Civil Aeronautics Manual 10

Certification and Approval of Import Aircraft and Related Products

FEDERAL AVIATION AGENCY

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Civil Aeronautics Manual 10

Certification and Approval of Import Aircraft and Related Products

Supplement No. 2, CAM 10 dated September 1959 — April 1, 1961

SUBJECT: Revision to CAM 10.

This supplement is issued to revise appendix A of CAM 10 to include Austria in the list of countries with which the United States has reciprocal import-export agreements for aeronautical products.

With the discontinuance of the distribution of individual amendments to the Civil Air Regulations, it is believed that the preamble material contained in the parts and amendments should be reproduced in the manuals. Therefore, this supplement incorporates into CAM 10 the *preamble* of Part 10 of the Civil Air Regulations which was adopted and effective March 28, 1955, and published in the Federal Register on April 1, 1955.

This preamble is set up as an addendum to CAM 10 and the page numbers are prefixed with the letter "P". It is recommended that these pages be retained in the back of the current CAM 10. Additional pages will be added as amendments to Part 10 are issued.

New or revised material is enclosed in black brackets on the pages submitted with this supplement. However, because the addendum containing the preamble to Part 10 is new in its entirety it is not so marked.

Remove the following pages:	*Insert the following new pages:*
III	III
3	3
	Addendum, pages P–1 through P–4

OSCAR BAKKE, *Director,*
Bureau of Flight Standards.

Attachments.

Federal Aviation Agency

Washington, D.C.

Civil Aeronautics Manual 10

Certification and Approval of Import Aircraft and Related Products

Supplement No. 1, CAM 10 dated September 1959 **October 15, 1960**

SUBJECT: Revision to CAM 10.

This supplement is issued to revise appendix A of CAM 10 to include Australia in the list of countries with which the United Sttaes has reciprocal import-export agreements for aeronautical products.

Remove the following page: 3

Insert the following new page: 3

Oscar Bakke

OSCAR BAKKE, *Director,*
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ATTACHMENT.

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Introductory Note

This manual contains Civil Air Regulations Part 10 dated March 28, 1955, the editorial changes required by Special Regulation SR-430 effective December 31, 1958, and two appendixes: Appendix A is a list of the countries with which the United States has reciprocal trade agreements for aeronautical products, and Appendix B contains the Special Civil Air Regulations which affect Part 10.

This manual supersedes Civil Aeronautics Manual 10 dated June 1959. As amendments and other pertinent materials pertaining to Part 10 are issued, they will be included in this manual.

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Certification and Approval of Import Aircraft and Related Products

Applicability and Definitions

10.0 *Applicability of this part.* This part establishes administrative requirements for the issuance of type and airworthiness certificates for aircraft, and of type certificates and approvals for related products, when such aircraft or products is manufactured in a foreign country with which the United States has concluded an agreement concerning the acceptance thereof for the purpose of export and import. In addition, this part establishes administrative requirements for the issuance of approvals for materials, parts, and appliances other than those sold in conjunction with a type certificated aircraft or related product when such material, part, or appliance is manufactured in a foreign country.

10.1 *Definitions.* As used in this part, terms are defined as follows:

(a) *Administration.*

(1) *Administrator.* The Administrator is the Administrator of the Federal Aviation Agency.

(2) *Approved.* Approved, when used alone or as modifying terms such as means, devices, specifications, etc., shall mean approved by the Administrator.

(b) *Design.*

(1) *Aircraft.* An aircraft means any contrivance now known or hereafter invented, used, or designed for navigation of or flight in the air.

(2) *Aircraft engine.* An aircraft engine means an engine used, or intended to be used, for propulsion of aircraft and includes all parts, appurtenances, and accessories thereof other than propellers.

(3) *Appliances.* Appliances means instruments, equipment, apparatus, parts, appurtenances, or accessories, of whatever description, which are used, or are capable of being or intended to be used, in the navigation, operation, or control of aircraft in flight (including parachutes and including communication equipment and any other mechanism or mechanisms installed in or attached to aircraft during flight), and which are not a part or parts of aircraft, aircraft engines, or propellers.

(4) *Product.* The term product, as used in this part, means:

(i) An aircraft,

(ii) An aircraft engine,

(iii) A propeller, or

(iv) Any appliance specified in the Civil Air Regulations as eligible for a type certificate.

(5) *Propeller.* A propeller includes all parts, appurtenances, and accessories thereof.

Type Certificates

10.10 *Eligibility.* A product which is manufactured in a foreign country with which the United States has concluded an agreement concerning the acceptance thereof for the purpose of export and import, is eligible for the issuance of a type certificate under this part. The application for a type certificate for a specified product shall be made upon a form and in a manner prescribed by the Administrator.

10.11 *Requirements for issuance.* A type certificate for a product shall be issued to an applicant when the government of the country in which the product was manufactured certifies that the product has been examined, tested, and found to comply with either paragraph (a) or paragraph (b) of this section.

(a) The airworthiness requirements prescribed in the Civil Air Regulations applicable to the product involved.[1]

[1] Separate airworthiness requirements are effective for various categories of aircraft, for aircraft engines, and for propellers in different parts of the Civil Air Regulations. When any one part is applicable all provisions therein including the administrative provisions are applicable.

(b) The applicable airworthiness requirements of the government of the country in which it was manufactured together with such other requirements as may be prescribed by the Administrator to provide a level of safety equivalent to the requirements prescribed in paragraph (a) of this section.

Airworthiness Certificates and Other Approvals

10.20 *Airworthiness certificates.* The requirements for the original issuance of airworthiness certificates for aircraft shall be in accordance with section 1.67(c) of this chapter.

10.21 *Approval of materials, parts, and appliances.*

(a) Materials, parts, and appliances manufactured in a foreign country shall be approved upon a basis and in a manner found necessary by the Administrator to implement the pertinent provisions of the Civil Air Regulations. The Administrator may adopt and publish such specifications as he finds necessary to administer this regulation, and shall incorporate therein such portions of the aviation industry, Federal, and military specifications respecting such materials, parts, and appliances as he finds appropriate.

Note: The provisions of this paragraph are intended to allow approval of materials, parts, and appliances under the system of Technical Standard Orders, or in conjunction with type certification procedures for an aircraft, or by any other form of approval by the Administrator.

(b) Any material, part, or appliance shall be deemed to have met the requirements for approval when the government of the country of manufacture certifies that the material, part, or appliance meets the pertinent specifications adopted by the Administrator, unless the Administrator finds, on the basis of data submitted in accordance with section 10.31, that the material, part, or appliance is otherwise inconsistent with the intent of the pertinent Civil Air Regulations.

Applicable Requirements

10.30 *Designation.* All aircraft, products, materials, parts, and appliances certificated or approved in accordance with this part shall be designated as "import" and clearly labeled as such.

10.31 *Data required.* Such technical data respecting the aircraft, product, material, part, or appliance, for which certification or approval is sought, shall be submitted as the Administrator finds necessary.

Appendix A

Countries With Which the United States Has Reciprocal Import-Export Agreements for Aeronautical Products

The United States has concluded agreements for reciprocal recognition of certificates of airworthiness for imported aircraft and for the export and import of other aeronautical products. An aircraft, engine or propeller manufactured in the countries listed below are eligible for an FAA type certificate under the requirements of Part 10. As new agreements are concluded, this list will be revised.

Australia
[Austria]
Belgium
Canada
Denmark
France
Italy
Netherlands
Norway
Spain
Sweden
Union of South Africa
United Kingdom
West Germany

Appendix B

Special Civil Air Regulations
Which Affect Part 10

SPECIAL CIVIL AIR REGULATION NO. SR-422

Effective: August 27, 1957
Adopted: July 23, 1957

Turbine-Powered Transport Category Airplanes of Current Design

Part 4b of the Civil Air Regulations contains rules governing the design of transport category airplanes. For a number of years, this part has established airworthiness requirements for this category of airplanes by prescribing detailed provisions to be met for the issuance of a type certificate. However, the advent of turbine-powered airplanes (jets, turboprops, etc.) has brought about operations at considerably higher speeds and altitudes than those involving reciprocating engine airplanes. These higher speeds and altitudes as well as certain inherent characteristics of turbine engines have introduced numerous new technical and design problems and have necessitated re-evaluation and amendment of many provisions in Part 4b.

In recent years the Board has amended Part 4b by introducing numerous technical provisions more specifically applicable to turbine-powered airplanes. These were included in amendments pertaining to structural, flight characteristic, powerplant installation, and other provisions. It is believed that Part 4b as now written is applicable to turbine-powered airplanes with but one exception; namely, airplane performance. In the future, further amendments to this part, other than those relating to performance, will be comparatively minor in nature mainly reflecting the latest experience in the certification and operation of these airplanes.

The performance requirements presently in Part 4b were first promulgated almost twelve years ago. They are now considered by the Board to be in a form not suitable for direct application to turbine-powered airplanes.

The administrator of Civil Aeronautics is in receipt of a large number of applications for type certification of turbine-powered airplanes. However, the so-called "non-retroactive"clause of section 4b.11(a) of Part 4b does not make applicable to a particular airplane type any amendment which is adopted after an application is filed by the manufacturer for type certification of that airplane. Thus, most of these airplanes are not now required to meet some of the latest effective provisions of Part 4b unless the Board prescribes otherwise. With so many applications for type certificates pending, it is essential that the Board establish adequate requirements which will effectively apply to the type certification of turbine-powered transport category airplanes. This Special Civil Air Regulation is being promulgated for that purpose.

This Special Civil Air Regulation is being made effective with respect to all turbine-powered transport category airplanes not yet certificated. In essence, it prescribes a revised set of performance requirements for turbine-powered airplanes and incorporates such of the recent amendments to Part 4b as the Administrator finds necessary to insure that the level of safety of turbine-powered airplanes is equivalent to that generally intended by Part 4b.

The performance requirements contained herein include not only the performance requirements necessary for the certification of an airplane, but also the complementary performance operating limitations as applicable under Parts 40, 41, and 42 of the Civil Air Regulations. In promulgating this new performance code, the Board intends that the resulting level of safety will be generally similar to the level of safety established by the performance code as expressed by the provisions now contained in Parts 4b and 40 (or 41 or 42 as appropriate) for reciprocating engine airplanes. To attain this, many of the performance provisions have been modified for better applicability to turbine-powered airplanes, some in the direction of liberalization, others in the direction of improvement in the required performance.

A significant change being made is the introduction of full temperature accountability in all stages of performance, except the landing distances required. The introduction of full temperature accountability will insure that the airplane's performance is satisfactory irrespective of the existing atmospheric temperature. The performance requirements heretofore applicable did not give sufficient assurance in this respect.

The reason for omitting the direct application of temperature accountability in the requirement for landing distances is that this stage of performance always has been treated in a highly empirical fashion whereby temperature effects are taken into account indirectly together with the effects of other operational factors. Long range studies on rationalization of airplane performance so far have not yielded a satisfactory solution to the landing stage of performance. The Board hopes, however, that continued studies will result in a solution of this problem in the near future.

The introduction of full temperature accountability has necessitated a complete re-evaluation of the minimum climb requirements. Since the prescribed climb must now be met at all temperatures rather than to be associated with standard temperature, the specific values of climb have been altered. In each instance, the change has been in the downward direction because, although the previous values were related to standard temperature, a satisfactory resultant climb performance was attained at temperatures substantially above standard. While values of minimum climb performance specified in the new code will tend to increase the maximum certificated weights of the airplane for the lower range of temperatures, they will limit these weights for the upper range of temperatures, giving adequate assurance of satisfactory climb performance at all temperatures.

In considering the various stages of flight where minimum values of climb have been heretofore established, the Board finds that in two of the stages (all-engines-operating en route and one-engine-inoperative en route) the establishment of minimum values of climb is unnecessary because, in the case of the all-engines-operating stage, it has been found not to be critical and the case of the one-engine-inoperative stage is now more effectively covered by the en route performance operating limitations.

Considering that the minimum climbs being prescribed affect mainly the maximum certificated weights of the airplane but not the maximum operating weights, the Board, in adopting the new performance code, places considerable emphasis on the ability of the airplane to clear obstacles on take-off and during flight. To this end, criteria for the take-off path, the en route flight paths, and the transition from take-off to the en route stage of flight have been prescribed to reflect realistic operating procedures. Temperature is fully accounted for in establishing all flight paths and an expanding clearance between the take-off path and the terrain or obstacles is required until the en route stage of flight is reached.

In order to insure that the objectives of the prescribed performance are in fact realized in actual operations, the manufacturer is required to establish procedures to be followed in the operation of the airplane in the various conditions specified in the regulation. These procedures, each designed for a specific airplane, will permit the operator to utilize the full performance capabilities of the airplane more readily than if the regulations prescribed all-inclusive procedures. The use of these procedures in determining compliance with the requirements governing take-off, en route, and landing stages, will also add considerable flexibility to the regulation.

The new performance requirements established more clearly than heretofore which of the performance limitations are conditions on the airworthiness certificate of the airplane. In addition to the maximum certificated take-off and landing weights, there are included limitations on the take-off distances and on the use of the airplane within the ranges of operational variables, such as altitude, temperature, and wind. Since these limitations are in the airworthiness certificate, they are applicable to all type operations conducted with the airplane.

The new performance code contains values for minimum climb expressed as gradients of climb, in percent, rather than as rates of climb, in feet per minute, as has been the case heretofore. The Board believes that the gradient of climb is more direct in expressing the performance margins of the airplane. Use of the gradient eliminates the influence of the stalling speed on the required climb. Heretofore, higher rates of climb were required for airplanes with higher stalling speeds. The only differentiation in the new code with respect to the required climb is between two and four-engine airplanes. This type of differentiation is of long standing in the regulations, being applicable to the one-engine-inoperative stage of flight. It is now being expanded to the take-off and approach stages.

The new performance requirements contained herein are based on the best information presently available to the Board. It is realized, however, that due to the present limited operating experience with turbine-powered transport airplanes, improvement in the requirements can be expected as a result of the direct application of the code to specific designs of new airplanes. There are certain areas in the new requirements where additional refinement of details might be advisable. This is so particularly in the case of the requirements pertaining to the landing stage of flight. It is anticipated that, after further study of the regulation and especially after its application in the design, certification, and operation of forthcoming turbine-powered airplanes, the desirability of changes may become more apparent. It is the intent of the Board to consider without delay such changes as might be found necessary. Only after the provisions of this Special Civil Air Regulation are reasonably verified by practical application will the Board consider incorporating them on a more permanent basis into Parts 4b, 40, 41, and 42 of the Civil Air Regulations.

This Special Civil Air Regulation is not intended to compromise the authority of the Administrator under section 4b.10 to impose such special conditions as he finds necessary in any particular case to avoid unsafe design features and otherwise to insure equivalent safety.

Interested persons have been afforded an opportunity to participate in the making of this regulation (21 F.R. 6091), and due consideration has been given to all relevant matter presented.

In consideration of the foregoing, the Civil Aeronautics Board hereby makes and promulgates the following Special Civil Air Regulation, effective August 27, 1957.

Contrary provisions of the Civil Air Regulations notwithstanding, all turbine-powered transport category airplanes for which a type certificate is issued after the effective date of this Special Civil Air Regulation shall comply with the following:

1. The provisions of Part 4b of the Civil Air Regulations, effective on the date of application for type certificate; and such of the provisions of all subsequent amendments to Part 4b, in effect prior to the effective date of this special regulation, as the Administrator finds necessary to insure that the level of safety of turbine-powered airplanes is equivalent to that generally intended by Part 4b.

2. In lieu of sections 4b.110 through 4b.125, and 4b.743 of Part 4b of the Civil Air Regulations, the following shall be applicable:

PERFORMANCE

4T.110 *General.*

(a) The performance of the airplane shall be determined and scheduled in accordance with, and shall meet the minima prescribed by, the provisions of sections 4T.110 through 4T.123. The performance limitations, information, and other data shall be given in accordance with section 4T.743.

(b) Unless otherwise specifically prescribed, the performance shall correspond with ambient atmospheric conditions and still air. Humidity shall be accounted for as specified in paragraph (c) of this section.

(c) The performance as affected by engine power and/or thrust shall be based on a relative humidity of 80 percent at and below standard temperatures and on 34 percent at and above standard temperatures plus 50° F. Between these two temperatures the relative humidity shall vary linearly.

(d) The performance shall correspond with the propulsive thrust available under the particular ambient atmospheric conditions, the particular flight conditions, and the relative humidity specified in paragraph (c) of this section. The available propulsive thrust shall correspond with engine power and/or thrust not exceeding the approved power and/or thrust less the installational losses and less the power and/or equivalent thrust absorbed by the accessories and services appropriate to the particular ambient atmospheric conditions and the particular flight condition.

4T.111 *Airplane configuration, speed, power, and/or thrust; general.*

(a) The airplane configuration (setting of wing and cowl flaps, air brakes, landing gear, propeller, etc.), denoted respectively as the take-off, en route, approach, and landing configurations, shall be selected by the applicant except as otherwise prescribed.

(b) It shall be acceptable to make the airplane configurations variable with weight, altitude, and temperature, to an extent found by the Administrator to be compatible with operating procedures required in accordance with paragraph (c) of this section.

(c) In determining the accelerate-stop distances, take-off flight paths, take-off distances, and landing distances, changes in the airplane's configuration and speed, and in the power and/or thrust shall be in accordance with procedures established by the applicant for the operation of the airplane in service, except as otherwise prescribed. The procedures shall comply with the provisions of subparagraphs (1) through (3) of this paragraph.

(1) The Administrator shall find that the procedures can be consistently executed in service by crews of average skill.

(2) The procedures shall not involve methods or the use of devices which have not been proven to be safe and reliable.

(3) Allowance shall be made for such time delays in the execution of the procedures as may be reasonably expected to occur during service.

4T.112 *Stalling speeds.*

the minimum steady flight speed at which the airplane is controllable, in

(a) The speed V_{s_0} shall denote the calibrated stalling speed, or knots, with:

(1) Zero thrust at the stalling speed, or engines idling and throttles closed if it is shown that the resultant thrust has no appreciable effect on the stalling speed;

(2) If applicable, propeller pitch controls in the position necessary for compliance with subparagraph (1) of this paragraph;

(3) The airplane in the landing configuration;

(4) The center of gravity in the most unfavorable position within the allowable landing range;

(5) The weight of the airplane equal to the weight in connection with which V_s is being used to determine compliance with a particular requirement.

(b) The speed V_{s_1} shall denote the calibrated stalling speed, or the minimum steady flight speed at which the airplane is controllable, in knots, with:

(1) Zero thrust at the stalling speed, or engines idling and throttles closed if it is shown that the resultant thrust has no appreciable effect on the stalling speed;

(2) If applicable, propeller pitch controls in the position necessary for compliance with subparagraph (1) of this paragraph; the air-

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plane in all other respects (flaps, landing gear, etc.) in the particular configuration corresponding with that in connection with which V_{s_1} is being used;

(3) The weight of the airplane equal to the weight in connection with which V_{s_1} is being used to determine compliance with a particular requirement.

(c) The stall speeds defined in this section shall be the minimum speeds obtained in flight tests conducted in accordance with the procedure of subparagraphs (1) and (2) of this paragraph.

(1) With the airplane trimmed for straight flight at a speed of 1.4 V_s and from a speed sufficiently above the stalling speed to insure steady conditions, the elevator control shall be applied at a rate such that the airplane speed reduction does not exceed one knot per second.

(2) During the test prescribed in subparagraph (1) of this paragraph, the flight characteristics provisions of section 4b.160 of Part 4b of the Civil Air Regulations shall be complied with.

4T.113 *Take-off; general.*

(a) The take-off data in sections 4T.114 through 4T.117 shall be determined under the conditions of subparagraphs (1) and (2) of this paragraph.

(1) At all weights, altitudes, and ambient temperatures within the operational limits established by the applicant for the airplane.

(2) In the configuration for take-off (see sec. 4T.111).

(b) Take-off data shall be based on a smooth, dry, hard-surfaced runway, and shall be determined in such a manner that reproduction of the performance does not require exceptional skill or alertness on the part of the pilot. In the case of seaplanes or float planes, the take-off surface shall be smooth water, while for skiplanes it shall be smooth dry snow. In addition, the take-off data shall be corrected in accordance with subparagraphs (1) and (2) of this paragraph for wind and for runway gradients within the operational limits established by the applicant for the airplane.

(1) Not more than 50 percent of nominal wind components along the take-off path opposite to the direction of take-off, and not less than 150 percent of nominal wind components along the take-off path in the direction of take-off.

(2) Effective runway gradients.

4T.114 *Take-off speeds.*

(a) The critical-engine-failure speed V_1, in terms of calibrated air speed, shall be selected by the applicant, but shall not be less than the minimum speed at which controllability by primary aerodynamic controls alone is demonstrated during the take-off run to be adequate to permit proceeding safely with the take-off using average piloting skill, when the critical engine is suddenly made inoperative.

(b) The minimum take-off safety speed V_2, in terms of calibrated air speed, shall be selected by the applicant so as to permit the gradient of climb required in section 4T.120 (a) and (b), but it shall not be less than:

(1) 1.2 V_{s_1} for two-engine propeller-driven airplanes and for airplanes without propellers which have no provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed.

(2) 1.15 V_{S_1} for propeller-driven airplanes having more than two engines and for airplanes without propellers which have provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed;

(3) 1.10 times the minimum control speed V_{MC}, established in accordance with section 4b.133 of Part 4b of the Civil Air Regulations.

(c) If engine failure is assumed to occur at or after the attainment of V_2, the demonstration in which the take-off run is continued to include the take-off climb, as provided in paragraph (a) of this section, shall not be required.

4T.115 *Accelerate-stop distance.*

(a) The accelerate-stop distance shall be the sum of the following:

(1) The distance required to accelerate the airplane from a standing start to the speed V_1;

(2) Assuming the critical engine to fail at the speed V_1, the distance required to bring the airplane to a full stop from the point corresponding with the speed V_1.

(b) In addition to, or in lieu of, wheel brakes, the use of other braking means shall be acceptable in determining the accelerate-stop distance, provided that such braking means shall have been proven to be safe and reliable, that the manner of their employment is such that consistent results can be expected in service, and that exceptional skill is not required to control the airplane.

(c) The landing gear shall remain extended throughout the accelerate-stop distance.

4T.116 *Take-off path.* The take-off path shall be considered to extend from the standing start to a point in the take-off where a height of 1,000 feet above the take-off surface is reached or to a point in the take-off where the transition from the take-off to the en route configuration is completed and a speed is reached at which compliance with section 4T.120(c) is shown, whichever point is at a higher altitude. The conditions of paragraphs (a) through (i) of this section shall apply in determining the take-off path.

(a) The take-off path shall be based upon procedures prescribed in accordance with section 4T.111(c).

(b) The airplane shall be accelerated on or near the ground to the speed V_2 during which time the critical engine shall be made inoperative at speed V_1 and shall remain inoperative during the remainder of the take-off.

(c) Landing gear retraction shall not be initiated prior to reaching the speed V_2.

(d) The slope of the airborne portion of the take-off path shall be positive at all points.

(e) After the V_2 speed is reached, the speed throughout the take-off path shall not be less than V_2 and shall be constant from the point where the landing gear is completely retracted until a height of 400 feet above the take-off surface is reached.

(f) Except for gear retraction and propeller feathering, the airplane configuration shall not be changed before reaching a height of 400 feet above the take-off surface.

(g) At all points along the take-off path starting at the point where the airplane first reaches a height of 400 feet above the take-off surface, the available gradient of climb shall not be less than 1.4 percent for two-engine airplanes and 1.8 percent for four-engine airplanes.

(h) The take-off path shall be determined either by a continuous demonstration take-off, or alternatively, by synthesizing from segments the complete take-off path.

(i) If the take-off path is determined by the segmental method, the provisions of subparagraphs (1) through (4) of this paragraph shall be specifically applicable.

(1) The segments of a segmental take-off path shall be clearly defined and shall be related to the distinct changes in the configuration of the airplane, in power and/or thrust, and in speed.

(2) The weight of the airplane, the configuration, and the power and/or thrust shall be constant throughout each segment and shall correspond with the most critical condition prevailing in the particular segment.

(3) The segmental flight path shall be based on the airplane's performance without ground effect.

(4) Segmental take-off path data shall be checked by continuous demonstrated take-offs to insure that the segmental path is conservative relative to the continuous path.

4T.117 *Take-off distance.* The take-off distance shall be the horizontal distance along the take-off path from the start of the take-off to the point where the airplane attains a height of 35 feet above the take-off surface as determined in accordance with 4T.116.

4T.118 *Climb; general.* Compliance shall be shown with the climb requirements of sections 4T.119 and 4T.120 at all weights, altitudes, and ambient temperatures, within the operational limits established by the applicant for the airplane. The airplane's center of gravity shall be in the most unfavorable position corresponding with the applicable configuration.

4T.119 *All-engine-operating landing climb.* In the landing configuration, the steady gradient of climb shall not be less than 4.0 per cent, with:

(a) All engines operating at the available take-off power and/or thrust;

(b) A climb speed not in excess of 1.4 V_{S_0}.

4T.120 *One-engine-inoperative climb.*

(a) *Take-off; landing gear extended.* In the take-off configuration at the point of the flight path where the airplane's speed first reaches V_1, in accordance with section 4T.116 but without ground effect, the steady gradient of climb shall be positive with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available take-off power and/or thrust existing in accordance with section 4T.116 at the time the airplane's landing gear is fully retracted;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time retraction of the airplane's landing gear is initiated;

(3) The speed equal to the speed V_2.

(b) *Take-off; landing gear retracted.* In the take-off configuration at the point of the flight path where the airplane's landing gear is fully retracted, in accordance with section 4T.116 but without ground effect, the steady gradient of climb shall not be less than 2.5 percent for two-engine airplanes and not less than 3.0 percent for four-engine airplanes, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the take-off power and/or thrust available at a height of 400 feet above the take-off surface and existing in accordance with section 4T.116;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time the airplane's landing gear is fully retracted;

(3) The speed equal to the speed V_2.

(c) *Final take-off.* In the en route configuration, the steady gradient of climb shall not be less than 1.4 percent for two-engine airplanes and not less than 1.8 percent for four-engine airplanes, at the end of the take-off path as determined by section 4T.116, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available maximum continuous power and/or thrust;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time retraction of the airplane's flaps is initiated;

(3) The speed equal to not less than 1.25 V_{S_1}.

(d) *Approach.* In the approach configuration such that V_{S_1} does not exceed 1.10 V_{S_0}, the steady gradient of climb shall not be less than 2.2 percent for two-engine airplanes and not less than 2.8 percent for four-engine airplanes, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available take-off power and/or thrust;

(2) The weight equal to the maximum landing weight;

(3) A climb speed in excess of 1.5 V_{S_1};

4T.121 *En route flight paths.* With the airplane in the en route configuration, the flight paths prescribed in paragraphs (a) and (b) of this section shall be determined at all weights, altitudes, and ambient temperatures within the limits established by the applicant for the airplane.

(a) *One engine inoperative.* The one-engine-inoperative net flight path data shall be determined in such a manner that they represent the airplane's actual climb performance diminished by a gradient of climb equal to 1.4 percent for two-engine airplanes and 1.8 percent for four-engine airplanes. It shall be acceptable to include in these data the variation of the airplane's weight along the flight path to take into account the progressive consumption of fuel and oil by the operating engine(s).

(b) *Two engines inoperative.* For airplanes with four engines, the two-engine–inoperative net flight path data shall be determined in such a manner that they represent the airplane's actual climb performance diminished by a gradient of climb equal to 0.6 percent. It shall be acceptable to include in these data the variation of the airplane's weight along the flight path to take into account the progressive consumption of fuel and oil by the operating engines.

(c) *Conditions.* In determining the flight paths prescribed in paragraphs (a) and (b) of this section, the conditions of subparagraphs (1) through (4) of this paragraph shall apply.

(1) The airplane's center of gravity shall be in the most unfavorable position.

(2) The critical engine(s) shall be inoperative, the remaining engine(s) operating at the available maximum continuous power and/or thrust.

(3) Means for controlling the engine cooling air supply shall be in the position which provides adequate cooling in the hot-day condition.

(4) The speed shall be selected by the applicant.

4T.122 *Landing distance.* The landing distance shall be the horizontal distance required to land and to come to a complete stop (to a speed of approximately 3 knots in the case of seaplanes or float planes) from a point at a height of 50 feet above the landing surface. Landing distances shall be determined for standard temperatures at all weights, altitudes, and winds within the operational limits established by the applicant for the airplane. The conditions of paragraphs (a) through (f) of this section shall apply.

(a) The airplane shall be in the landing configuration. During the landing, changes in the airplane's configuration, in power and/or thrust, and in speed shall be in accordance with procedures established by the applicant for the operation of the airplane in service. The procedures shall comply with the provisions of section 4T.111(c).

(b) The landing shall be preceded by a steady gliding approach down to the 50-foot height with a calibrated air speed of not less than 1.3 V_{s_0}.

(c) The landing distance shall be based on a smooth, dry, hard-surfaced runway, and shall be determined in such a manner that reproduction does not require exceptional skill or alertness on the part of the pilot. In the case of seaplanes or float planes, the landing surface shall be smooth water, while for skiplanes it shall be smooth dry snow. During landing, the airplane shall not exhibit excessive vertical acceleration, a tendency to bounce, nose over, ground loop, porpoise, or water loop.

(d) The landing distance shall be corrected for not more than 50 percent of nominal wind components along the landing path opposite to the direction of landing and not less than 150 percent of nominal wind components along the landing path in the direction of landing.

(e) During landing, the operating pressures on the wheel braking system shall not be in excess of those approved by the manufacturer of the brakes, and the wheel brakes shall not be used in such a manner as to produce excessive wear of brakes and tires.

(f) If the Administrator finds that a device on the airplane other than wheel brakes has a noticeable effect on the landing distance and if the device depends upon the operation of the engine and the effect of such a device is not compensated for by other devices in the event of engine failure, the landing distance shall be determined by assuming the critical engine to be inoperative.

4T.123 *Limitations and information.*

(a) *Limitations.* The performance limitations on the operation of the airplane shall be established in accordance with subparagraphs (1) through (4) of this paragraph. (See also sec. 4T.743.)

(1) *Take-off weights.* The maximum take-off weights shall be established at which compliance is shown with the generally applicable provisions of this regulation and with section 4T.120 (a), (b), and (c) for altitudes and ambient temperatures within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(2) *Landing weights.* The maximum landing weights shall be established at which compliance is shown with the generally applicable provisions of this regulation and with sections 4T.119 and 4T.120(d) for altitudes and ambient temperatures within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(3) *Take-off and accelerate-stop distances.* The minimum distances required for takeoff shall be established at which compliance is shown with the generally applicable provisions of this regulation and with sections 4T.115 and 4T.117 for weights, altitudes, temperatures, wind components, and runway gradients, within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(4) *Operational limits.* The operational limits of the airplane shall be established by the applicant for all variable factors required in showing compliance with this regulation (weight, altitude, temperature, etc.). (See secs. 4T.113(a) (1) and (b), 4T.118, 4T.121, and 4T.122.)

(b) *Information.* The performance information on the operation of the airplane shall be scheduled in compliance with the generally applicable provisions of this regulation and with sections 4T.116, 4T.121, and 4T.122 for weights, altitudes, temperatures, wind components, and runway gradients, as these may be applicable, within the operational limits of the airplane (see subparagraph (a)(4) of this section). In addition, the performance information specified in subparagraphs (1) through (3) of this paragraph shall be determined by extrapolation and scheduled for the ranges of weights between the maximum landing and maximum take-off weights established in accordance with subparagraphs (a)(1) and (a)(2) of this section. (See also sec. 4T.743.)

(1) Climb in the landing configuration (see sec. 4T.119);

(2) Climb in the approach configuration (see sec. 4T.120(d));

(3) Landing distance (see sec. 4T.122).

AIRPLANE FLIGHT MANUAL

4T.743 *Performance limitations, information, and other data.*

(a) *Limitations.* The airplanes' performance limitations shall be given in accordance with section 4T.123(a).

(b) *Information.* The performance information prescribed in section 4T.123(b) for the application of the operating rules of this regulation shall be given together with descriptions of the conditions, air speeds, etc., under which the data were determined.

(c) *Procedures.* For all stages of flight, procedures shall be given with respect to airplane configurations, power and/or thrust settings, and indicated air speeds, to the extent such procedures are related to the limitations and information set forth in accordance with paragraphs (a) and (b) of this section.

(d) *Miscellaneous.* An explanation shall be given of significant or unusual flight or ground handling characteristics of the airplane.

3. In lieu of sections 40.70 through 40.78, 41.27 through 41.36(d), and 42.70 through 42.83, of Parts 40, 41, and 42 of the Civil Air Regulations, respectively, the following shall be applicable:

OPERATING RULES

40T.80 *Transport category airplane operating limitations.*

(a) In operating any passenger-carrying transport category airplane certificated in accordance with the performance requirements of this regulation, the provisions of sections 40T.80 through 40T.84 shall be complied with, unless deviations therefrom are specifically authorized by the Administrator on the ground that the special circumstances of a particular case make a literal observance of the requirements unnecessary for safety.

(b) The performance data in the Airplane Flight Manual shall be applied in determining compliance with the provisions of sections 40T.81 through 40T.84. Where conditions differ from those for which specific tests were made compliance shall be determined by approved interpolation or computation of the effects of changes in the specific variables if such interpolations or computations give results substantially equalling in accuracy the results of a direct test.

40T.81 *Airplane's certificate limitations.*

(a) No airplane shall be taken off at a weight which exceeds the take-off weight specified in the Airplane Flight Manual for the elevation of the airport and for the ambient temperature existing at the time of the take-off. (See secs. 4T.123(a)(1) and 4T.743(a).)

(b) No airplane shall be taken off at a weight such that, allowing for normal consumption of fuel and oil in flight to the airport of destination, the weight on arrival will exceed the landing weight specified in the Airplane Flight Manual for the elevation of the airport of destination and for the ambient temperature anticipated there at the time of landing. (See secs. 4T.123(a)(2) and 4T.743(a).)

(c) No airplane shall be taken off at a weight which exceeds the weight shown in the Airplane Flight Manual to correspond with the minimum distance required for take-off on the runway to be used. The take-off distance shall correspond with the elevation of the airport, the effective runway gradient, and the ambient temperature and wind component existing at the time of take-off. (See secs. 4T.123(a)(3) and 4T.743 (a).)

(d) No airplane shall be operated outside the operational limits specified in the Airplane Flight Manual. (See secs. 4T.123(a)(4) and 4T.743(a).)

40T.82 *Take-off obstacle clearance limitations.* No airplane shall be taken off at a weight in excess of that shown in the Airplane Flight Manual to correspond with a take-off path which clears all obstacles either by at least a height equal to (35 + 0.01D) feet vertically, where D is the distance out along the intended flight path from the end of the runway in feet, or by at least 200 feet horizontally within the airport boundaries and by at least 300 feet horizontally after passing beyond the boundaries. In determining the allowable deviation of the flight path in order to avoid obstacles by at least the distances prescribed, it shall be assumed that the airplane is not banked before reaching a height of 50 feet as shown by the take-off path data in the Airplane Flight Manual, and that a maximum bank thereafter does not exceed 15 degrees. The take-off path considered shall be for the elevation of the airport, the effective runway gradient, and for the ambient temperature and wind component existing at the time of take-off. (See secs. 4T.123(b) and 4T.743(b).)

40T. 83 *En route limitations.*

(a) *One engine inoperative.* No airplane shall be taken off at a weight in excess of that which, according to the one-engine-inoperative en route net flight path data shown in the Airplane Flight Manual, will permit compliance with either subparagraph (1) or subparagraph (2) of this paragraph at all points along the route. The net flight path used shall be for the ambient temperatures anticipated along the route. (See secs. 4T.123(b) and 4T.743(b).)

(1) The slope of the net flight path shall be positive at an altitude of at least 1,000 feet above all terrain and obstructions along the route within 5 miles on either side of the intended track.

(2) The net flight path shall be such as to permit the airplane to continue flight from the cruising altitude to an alternate airport where a landing can be made in accordance with the provisions of section 40T.84 (b), the net flight path clearing vertically by at least 2,000 feet all terrain and obstructions along the route within 5 miles on either side of the intended track. The provisions of subdivisions (i) through (vii) of this paragraph shall apply.

(i) The engine shall be assumed to fail at the most critical point along the route.

(ii) The airplanes shall be assumed to pass over the critical obstruction following engine failure at a point no closer to the critical obstruction than the nearest approved radio navigational fix, except that the Administrator may authorize a procedure established on a different basis where adequate operational safeguards are found to exist.

(iii) The net flight path shall have a positive slope at 1,000 feet above the airport used as the alternate.

(iv) An approved method shall be used to account for winds which would otherwise adversely affect the flight path.

(v) Fuel jettisoning shall be permitted if the Administrator finds that the operator has an adequate training program, proper instructions are given to the flight crew, and all other precautions are taken to insure a safe procedure.

(vi) The alternate airport shall be specified in the dispatch release and shall meet the prescribed weather minima.

(vii) The consumption of fuel and oil after the engine becomes inoperative shall be that which is accounted for in the net flight path data shown in the Airplane Flight Manual.

(b) *Two engines inoperative.* No airplane shall be flown along an intended route except in compliance with either subparagraph (1) or subparagraph (2) of this paragraph.

(1) No place along the intended track shall be more than 90

minutes away from an airport at which a landing can be made in accordance with the provisions of section 40T.84(b), assuming all engines to be operating at cruising power.

(2) No airplane shall be taken off at a weight in excess of that which, according to the two-engine-inoperative en route net flight path data shown in the Airplane Flight Manual, will permit the airplane to continue flight from the point where two engines are assumed to fail simultaneously to an airport where a landing can be made in accordance with the provisions of section 40T.84(b), the net flight path having a positive slope at an altitude of at least 1,000 feet above all terrain and obstructions along the route within 5 miles on either side of the intended track or at an altitude of 5,000 feet, whichever is higher. The net flight path considered shall be for the ambient temperatures anticipated along the route. The provisions of subdivision (i) through (iii) of this subparagraph shall apply. (See secs. 4T.123(b) and 4T.743(b).)

(i) The two engines shall be assumed to fail at the most critical point along the route.

(ii) If fuel jettisoning is provided, the airplane's weight at the point where the two engines are assumed to fail shall be considered to be not less than that which would include sufficient fuel to proceed to the airport and to arrive there at an altitude of at least 1,000 feet directly over the landing area.

(iii) The consumption of fuel and oil after the engines become inoperative shall be that which is accounted for in the net flight path data shown in the Airplane Flight Manual.

40T.84 *Landing limitations.*

(a) *Airport of destination.* No airplane shall be taken off at a weight in excess of that which, in accordance with the landing distances shown in the Airplane Flight Manual for the elevation of the airport of intended destination and for the wind conditions anticipated there at the time of landing, would permit the airplane to be brought to rest at the airport of intended destination within 60 percent of the effective length of the runway from a point 50 feet directly above the intersection of the obstruction clearance plane and the runway. The weight of the airplane shall be assumed to be reduced by the weight of the fuel and oil expected to be consumed in flight to the airport of intended destination. Compliance shall be shown with the conditions of subparagraphs (1) and (2) of this paragraph. (See secs. 4T.123(b) and 4T.743(b).)

(1) It shall be assumed that the airplane is landed on the most favorable runway and direction in still air.

(2) It shall be assumed that the airplane is landed on the most suitable runway considering the probable wind velocity and direction and taking due account of the ground handling characteristics of the airplane and of other conditions (i.e., landing aids, terrain, etc.). If full compliance with the provisions of this subparagraph is not shown, the airplane may be taken off if an alternate airport is designated which permits compliance with paragraph (b) of this section.

(b) *Alternate airport.* No airport shall be designated as an alternate airport in a dispatch release unless the airplane at the weight anticipated at the time of arrival at such airport can comply with the provisions of paragraph (a) of this section, provided that the airplane can be brought to rest within 70 percent of the effective length of the runway.

SPECIAL CIVIL AIR REGULATION NO. SR-422A

Adopted: July 2, 1958
Effective: July 2, 1958

Turbine-Powered Transport Category Airplanes of Current Design

On July 23, 1957, the Board adopted Special Civil Air Regulation No. SR-422 which sets forth airworthiness requirements applicable to the type certification and operation of turbine-powered transport category airplanes for which a type certificate is issued after August 27, 1957. Included in that regulation was a new set of performance requirements, with respect to which the Board indicated that consideration would be given to any changes found necessary as a result of further study and experience. The preamble to SR-422 contains the relevant considerations leading to its promulgation and is considered to provide the basic background for this regulation.

Since the adoption of SR-422, considerable study has been devoted to the new performance requirements by all interested parties. As a result of these studies and of further experience gained in the design, certification, and operation of turbine-powered airplanes, certain issues with respect to SR-422 require re-evaluation. This regulation reflects the resolution of most of the outstanding issues in the light of the best information presently available to the Board.

The following provisions of this regulation differ from, or are additional to, the provisions of SR-422; Introductory paragraph; item 1; sections 4T.111(c); 4T.112; 4T.114 (b), (b)(1), (b)(4), and (c); introductory paragraph of 4T.116; 4T.116 (b), (c), (e), and (g); 4T.117; 4T.117a; 4T.119; 4T.120 (a), (a)(1), (b), (b)(1), (c), (c)(2), (c)(3), (d), and (d)(3); 4T.121 (a) and (b); introductory paragraph of 4T.122; 4T.122 (b), (f), and (g); 4T.123 (a)(1), (a)(2), (a)(3), and (b); 4T.743(c); 40T.81 (b) and (c); 40T.82; 40T.83 (a)(2)(iii), (b)(2), and (b)(2)(ii); item 4; and item 5. Of these provisions, the following differ from those proposed in Civil Air Regulations Draft Release No. 58-6: sections 4T.111(c); 4T.112(a)(4); 4T.114 (b)(4), (c), (c)(2), (c)(3), and (c)(4); 4T.116 (c) and (e); 4T.117 (b)(1) and (b)(2); 4T.119(a); 4T.120(a); 40T.81(c) and 43T.11(c).

With respect to the applicability of this regulation, experience with certification under SR-422 indicates that a lead time of about two months between the date of adoption of the regulation and the date of issuance of the type certificate should provide a reasonable period of time within which to show compliance with this regulation. In view of this, and in the interest of having uniform regulations applicable to most of the turbine-powered airplanes, it is considered advisable to have this regulation apply to all such airplanes for which a type certificate is issued after September 30, 1958. Turbine-powered transport category airplanes for which a type certificate is issued on or prior to September 30, 1958, may comply with the provisions of this regulation in lieu of SR-422. If this option is exercised, it is intended that compliance be shown with all the provisions of this regulation and it is not intended to permit a showing of compliance with portions of this regulation and portions of SR–422.

The provisions of this regulation involve the following technical issues:

A substantive change is made by introducing an all-engines-operating take-off in establishing the take-off distance. Presently, the take-off distance is based only on a one-engine-out take-off. To insure that an adequate margin of safety will exist for day-in and day-out operations, the minimum take-off distance is being related to both the one-engine-inoperative distance now prescribed and to the distance with all engines operating, with a factor of 1.15 being applied to the latter.

There are also included important changes with respect to the speeds applicable to the take-off path. The provisions of SR–422 prescribe that the airplane shall be accelerated on or near the ground to the speed V_2. This provision has been subject to varying interpretations having a marked difference in effect on the resultant level of performance. The issue in this matter is whether or not the airplane should be permitted to lift off the runway at some speed below V_2. Because of the increased acceleration of turbine-powered airplanes, the tendency to overshoot the lift-off speed will be greater than on piston-engine airplanes and this tendency increases with the reduction in weight of the airplane. To restrict lift-off to the minimum take-off safety speed V_2 would unduly extend the take-off distance in cases where such overshooting of speed occurs. Such a restriction would be unnecessarily conservative and would not reflect realistic take-off procedures. For these reasons this regulation permits the airplane to lift off the ground at a speed lower than the V_2 speed, but prescribes certain limiting conditions. The lift-off speed is related to a rotational speed V_R which must not be less than 95 percent of the minimum V_2 speed and must be 10 percent greater than a speed at which no hazardous characteristics are displayed by the airplane, such as a relatively high drag condition or a ground stall. The V_2 speed has been re-defined to take into account the increment in speed arising from overshoot tendencies. Under the new definition, the minimum V_2 speed corresponds with the minimum take-off safety speed as now defined in SR–422. With respect to the take-off path, the V_2 speed is required to be attained prior to reaching a height of 35 feet above the take-off surface and thus is related to the selection of the rotational speed. Further, there is a revision which requires V_2 to be maintained as close as practicable at a constant value from the 35-foot point to a height of 400 feet above the take-off surface. This speed is the speed at which the prescribed minimum take-off gradients must be met.

There is introduced in this regulation the concept of unbalanced take-off field lengths. SR–422 does not preclude unbalancing of field lengths, provided that the unbalancing is within the length of the runway. Other countries have employed unbalancing with respect to so-called "stopways" and "clearways." It appears that United States operators ultimately will find it advantageous to resort to the use of unbalancing, but probably not to the same extent as practiced in other countries. On the premise that only clearways will be utilized, the amendments have been formulated accordingly. Clearways, as defined herein, are areas not suitable for stopping the airplane in the event of an aborted take-off, but adequate to provide additional take-off distance for climb-out. To safeguard operations utilizing clearways, there is introduced the concept of a take-off run which operationally relates to the determination of the minimum runway length required. The take-off run is defined as the greater of the horizontal distances along the take-off path to a given point with one engine inoperative or with all engines operating, with a margin of 15 percent being added to the latter. The take-off run is measured from the beginning of take-off to a point equidistant between the point where the airplane lifts off and the point where a height of 35 feet is reached. The required runway length must not be less than the take-off run nor less than the accelerate stop distance.

According to the definition given, a clearway is subjected to the control of the airport authorities. It is not intended, however, that there be ownership by the airport authorities of the area in which the clearway lies. The objective for requiring control by the airport authorities is to insure that no flight will be initiated using a clearway unless it is determined with certainty that no movable obstacle will exist within the clearway when the airplane flies over.

It is anticipated that the introduction of clearways will offer further possibilities of increasing the utility of existing airport facilities in this country. When such areas can be integrated into existing facilities, economical benefits will accrue to the community and the operators. In addition, since clearways are presently available at some of the airports in other countries, United States operators will have the opportunity of taking advantage of such facilities.

There are included changes with respect to the prescribed minimum altitude of 1,000 feet relative to the take-off path and to the one-engine-inoperative and two-engine-inoperative requirements applicable to the vicinity of the airport. Heretofore, the Civil Air Regulations have incorporated the reference altitude of 1,000 feet in respect of performance criteria over the airport. Obscure as is the significance of this altitude operationally, the altitude of 1,500 feet has worldwide precedent of being used as the altitude above the airport at which, generally, IFR approaches are initiated and go-around procedures executed. For this reason, the changes made extend the take-off path to a minimum altitude of 1,500 feet and make this altitude applicable to the prescribed performance criteria above the airport for the one- and two-engine-inoperative en route requirements. It is not anticipated that these changes will create any problems with respect to the en route stages of flight; however, it is realized that a further extension of the take-off path might add to the problem of obtaining accurate data on obstacles relatively distant from the airport. The Board finds that the extension of the flight path to 1,500 feet is warranted in light of the operational significance of this altitude and because the extended flight paths will provide more fully for adequate terrain clearance at the end of the take-off path.

There is included a change with respect to the take-off path whereby the take-off flight path is established as starting from a 35-foot height at the end of the take-off distance and a net take-off flight is prescribed for operational use. This latter change is for consistency with the specification of net flight paths for the en route stages of flight and to simplify determination of obstacle clearances operationally. The net flight path is specified to be the actual flight path diminished by a gradient of 1.0 percent. It is intended that the net flight path be obtained from the gross flight path by simple geometric means.

The change in the altitude from 1,000 to 1,500 feet previously mentioned, as well as a re-evaluation in other respects of some of the climb gradients in SR-422, justify certain changes. The gradients of 1.4 and 1.8 applicable to the take-off path and the final take-off climb are being reduced to 1.2 and 1.7 for two-engine and four-engine airplanes, respectively. In addition, the gradients of 1.4 and 1.8 in the one-engine-inoperative en route case are being reduced to 1.1 and 1.6, respectively.

Changes are made with respect to the one-engine-inoperative take-off climb by interrelating more realistically the prescribed airplane configuration, weight, and power. These changes, in effect, permit meeting the prescribed gradients of climb at slightly higher airplane weights than would be possible under the presently effective provisions.

There is included a change to the provisions applicable to the one-engine-inoperative take-off climb with landing gear extended which increases the prescribed minimum gradient from substantially zero to 0.5 percent for four-engine airplanes. This change is made to attain consistency in the difference between gradients applicable to twins and fours.

Changes are incorporated in connection with the two-engine-inoperative en route requirement. Representations have been made that the gradient of 0.6 percent now prescribed is unduly conservative. On the other hand, it has been pointed out that the fuel requirements for this case are not realistically covered. Both of these contentions warrant consideration and changes are included which reduce the margin gradient from 0.6 to 0.5 percent, reduce the prescribed altitude from 5,000 to 2,000 feet, and require scheduling the flight so that there is sufficient fuel on board to reach the airport and subsequently to fly for 15 minutes at cruise power or thrust.

Changes are also made relative to the approach and landing stages of flight. There is a new provision which requires the establishment of procedures for the execution of missed approaches and balked landings. A question has been raised as to whether the speed limitation of 1.5 V_s applicable to the approach condition is realistically related to the normal day-in and day-out landing procedures. To insure that it will be so related, it is required that the speed used for demonstrating the approach climb be established consistent with the landing procedures, but that it not exceed 1.5 V_s. In addition, the approach gradient of 2.8 percent prescribed for four-engine airplanes is being reduced to 2.7 percent to obtain consistency in the differences between gradients applicable to twins and fours.

A change is made to the "all-engines-operating landing climb" provisions which now require a 4.0 percent gradient of climb in the landing configuration. On the premise that requiring the landing configuration during the climb after a balk is unduly conservative, consideration was given to a proposal to permit showing of compliance with the 4.0 percent gradient of climb in the configuration which would exist 5 seconds after the initiation of the climb. Further study of this proposal indicated that such a rule would tend to introduce complications in design and lead to less favorable operating procedures which ultimately would not contribute to safety. One of the most important factors in connection with this configuration is the response of the engines to throttle movement. Therefore, there is a provision which requires that the power used in showing compliance with the climb gradient be that power or thrust attained 8 seconds after initiation of movement of the power controls to the take-off position from the minimum flight idle position. In addition, for consistency with the procedures used for determining the landing distance, the speed limitation of 1.4 V_s is reduced to 1.3 V_s. Concern has been indicated to the effect that any reduction in the prescribed gradient of 4.0 percent might not insure in all cases the ability of the airplane to continue a safe climb after a balk. To provide a further safeguard, the take-off weight-altitude-temperature limitations (WAT limitations stemming from the application of the one-engine-inoperative take-off climb requirements) are being made applicable to the maximum landing weight at the airport of landing. In the past, the landing weight limitations were applicable to the airport of destination but not to the weather alternates. This regulation makes both the take-off weight and landing weight limitations equally applicable to the airport of destination and the weather alternates. In view of the aforementioned changes, a reduction of the required climb gradient from 4.0 to 3.2 percent is justified and included in this regulation.

In addition to the substantive changes which have been discussed, there are three significant changes of a clarifying nature. The first deals with the determination of the landing distance as affected by devices or means other than wheel brakes. There is included a provision similar to the one applicable to the accelerate-stop distance for application to the landing distance. This provision permits the use of means other than wheel brakes in the determination of the landing distance. Additionally, there is a change to the provision which requires in some cases the determination of the landing distance with one engine inoperative. It is believed that the new requirement expresses the intent more clearly. One of the more obvious applications of this provision is in respect of turbopropeller airplanes. Such airplanes usually are landed with the propellers in a relatively high drag position. If one of the engines becomes inoperative, its propeller would be expected to be in a relativly low drag position with the consequence of a longer landing distance than with all engines operating. In such a case it is required that the landing distance be determined with one engine inoperative unless use could be made by the crew of other means (e.g., reverse thrust not otherwise considered in determining the landing distance) which would reduce the landing distance at least to that determined for all-engine operation.

The second clarification being included deals with the provision setting forth the procedures which must be included in the Airplane Flight Manual. This provision in SR–422 does not make clear what procedures are involved and whether the procedures are considered to be limitations on the operation of the airplane. The clarification in language specifies that the procedures which are included with the performance limitations shall be considered only as guidance material.

The third clarification concerns the applicability of the performance limitations prescribed in SR–422. These consist of the "certificate limitations" and the "operating limitations." The former relate to maximum take-off and landing weights, minimum take-off distances, accelerate-stop distances, and the operational limits imposed upon the airplane. These limitations, being part of the conditions of the type and airworthiness certificates, must be complied with at all times irrespective of the type of operation being conducted (e.g., air carrier, private, cargo). The "operating limitations," distinct from the "certificate limitations," are only applicable when required by the operating parts of the regulations (Parts 40, 41, and 42 require compliance for passenger operations). Although it appeared that previous Board pronouncements regarding this general principle as well as the explanation contained in the preamble to SR–422 would make the issue quite clear, it has come to the Board's attention that there is still some misunderstanding of this matter. Apparently this misunderstanding stems from the fact that SR–422 prescribes operating rules for air carrier operations which contain both the "certificate limitations" and the "operating limitations" while no prescription is given to non-air-carrier operations; thus giving an impression that not even the "certificate limitations" are applicable to non-air-carriers. The inclusion of "certificate limitations" for air carrier operations with the "operating limitations" was meant only to provide the operators with the convenience of having together the complete prescription of the applicable performance limitations, notwithstanding that such an inclusion, in fact, duplicates the general requirement of compliance with the "certificate limitations" contained in the Airplane Flight Manual. In view of the possible misunderstanding which might exist from the aforementioned inclusion, there are included in this regulation the same "certificate limitations" for application to all operations under the provisions of Part 43 of the Civil Air Regulations.

In addition, other changes of a minor nature are included herein, the most significant of which is the generalization of the stall speed V_s, eliminating reference to V_{s_0} and V_{s_1}.

Of the changes to SR–422 made in this regulation, there are a number which might require further consideration as studies continue and as additional experience is gained with the application of these new rules. Several of these involve new concepts with which U.S. operators have had little or no experience. These entail the requirements relative to unbalanced field lengths with respect to clearways, to the rotational speed, and to the all-engine take-off distance. Strong representation has been made to the Board to the effect that the numerical factors applicable to the aforementioned rules are too high and should be reduced pending further experience. The Board considers that it would not be in the public interest to reduce any of these factors until such time as further experience indicates that they are in fact overly conservative. Realizing, however, that these issues are of considerable importance in prescribing a practicable level of performance, the Board stands ready to reconsider the relevant provisions of this regulation at such time as substantiating information is received.

There are areas other than those previously mentioned where additional refinement of details may be advisable. This is so particularly in the case of the requirements pertaining to the landing stage of flight, to the take-off lateral clearances, and to the two-engine-inoperative en route gradient margin. It is anticipated that, after further study of the regulation and especially after its application in the design, certification, and operation of forthcoming turbine-powered airplanes, the desirability of changes may become more apparent. It is the intent of the Board to consider without delay such changes as might be found necessary. Only after the provisions of this Special Civil Air Regulation are reasonably verified by practical application will the Board consider incorporating them on a more permanent basis into Parts 4b, 40, 41, 42, and 43 of the Civil Air Regulations.

This Special Civil Air Regulation is not intended to compromise the authority of the Administrator under section 4b.10 to impose such special conditions as he finds necessary in any particular case to avoid unsafe design features and otherwise to insure equivalent safety.

Interested persons have been afforded an opportunity to participate in the making of this regulation (23 F.R. 2139), and due consideration has been given to all relevant matter presented.

In consideration of the foregoing, the Civil Aeronautics Board hereby makes and promulgates the following Special Civil Air Regulation, effective July 2, 1958:

Contrary provisions of the Civil Air Regulations notwithstanding, all turbine-powered transport category airplanes for which a type certificate is issued after August 27, 1957, shall comply with Special Civil Air Regulation No. SR–422 or, alternatively, with the following provisions, except that those airplanes for which a type certificate is issued after September 30, 1958, shall comply with the following provisions:

1. The provisions of Part 4b of the Civil Air Regulations, effective on the date of application for type certificate; and such of the provisions of all subsequent amendments to Part 4b, in effect prior to August 27, 1957, as the Administrator finds necessary to insure that the level of safety of turbine-powered airplanes is equivalent to that generally intended by Part 4b.

2. In lieu of sections 4b.110 through 4b.125, and 4b.743 of Part 4b of the Civil Air Regulations, the following shall be applicable:

PERFORMANCE

4T.110 *General.*

(a) The performance of the airplane shall be determined and scheduled in accordance with, and shall meet the minima prescribed by, the provisions of sections 4T.110 through 4T.123. The performance limitations, information, and other data shall be given in accordance with section 4T.743.

(b) Unless otherwise specifically prescribed, the performance shall correspond with ambient atmospheric conditions and still air. Humidity shall be accounted for as specified in paragraph (c) of this section.

(c) The performance as affected by engine power and/or thrust shall be based on a relative humidity of 80 percent at and below standard temperatures and on 34 percent at and above standard temperatures plus 50° F. Between these two temperatures the relative humidity shall vary linearly.

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(d) The performance shall correspond with the propulsive thrust available under the particular ambient atmospheric conditions, the particular flight condition, and the relative humidity specified in paragraph (c) of this section. The available propulsive thrust shall correspond with engine power and/or thrust not exceeding the approved power and/or thrust less the installational losses and less the power and/or equivalent thrust absorbed by the accessories and services appropriate to the particular ambient atmospheric conditions and the particular flight condition.

4T.111 *Airplane configuration, speed, power, and/or thrust; general.*

(a) The airplane configuration (setting of wing and cowl flaps, air brakes, landing gear, propeller, etc.), denoted respectively as the take-off, en route, approach, and landing configurations, shall be selected by the applicant except as otherwise prescribed.

(b) It shall be acceptable to make the airplane configurations variable with weight, altitude, and temperature, to an extent found by the Administrator to be compatible with operating procedures required in accordance with paragraph (c) of this section.

(c) In determining the accelerate-stop distances, take-off flight paths, take-off distances, and landing distances, changes in the airplane's configuration and speed, and in the power and/or thrust shall be in accordance with procedures established by the applicant for the operation of the airplane in service, except as otherwise prescribed. In addition, procedures shall be established for the execution of balked landings and missed approaches associated with the conditions prescribed in sections 4T.119 and 4T.120(d), respectively. All procedures shall comply with the provisions of subparagraphs (1) through (3) of this paragraph.

(1) The Administrator shall find that the procedures can be consistently executed in service by crews of average skill.

(2) The procedures shall not involve methods or the use of devices which have not been proven to be safe and reliable.

(3) Allowance shall be made for such time delays in the execution of the procedures as may be reasonably expected to occur during service.

4T.112 *Stalling speeds.*

(a) The speed V_s shall denote the calibrated stalling speed, or the minimum steady flight speed at which the airplane is controllable, in knots, with:

(1) Zero thrust at the stalling speed, or engines idling and throttles closed if it is shown that the resultant thrust has no appreciable effect on the stalling speed;

(2) If applicable, propeller pitch controls in the position necessary for compliance with subparagraph (1) of this paragraph; the airplane in all other respects (flaps, landing gear, etc.) in the particular configuration corresponding with that in connection with which V_s is being used;

(3) The weight of the airplane equal to the weight in connection with which V_s is being used to determine compliance with a particular requirement;

(4) The center of gravity in the most unfavorable position within the allowable range.

(b) The stall speed defined in this section shall be the minimum speed obtained in flight tests conducted in accordance with the procedure of subparagraphs (1) and (2) of this paragraph.

(1) With the airplane trimmed for straight flight at a speed of 1.4 V_s and from a speed sufficiently above the stalling speed to insure steady conditions, the elevator control shall be applied at a rate such that the airplane speed reduction does not exceed one knot per second.

(2) During the test prescribed in subparagraph (1) of this paragraph, the flight characteristics provisions of section 4b.160 of Part 4b of the Civil Air Regulations shall be complied with.

4T.113 *Take-off; general.*

(a) The take-off data in sections 4T.114 through 4T.117 shall be determined under the conditions of subparagraphs (1) and (2) of this paragraph.

(1) At all weights, altitudes, and ambient temperatures within the operational limits established by the applicant for the airplane.

(2) In the configuration for take-off (see sec. 4T.111).

(b) Take-off data shall be based on a smooth, dry, hard-surfaced runway and shall be determined in such a manner that reproduction of the performance does not require exceptional skill or alertness on the part of the pilot. In the case of seaplanes or float planes, the take-off surface shall be smooth water, while for skiplane it shall be smooth dry snow. In addition, the take-off data shall be corrected in accordance with subparagraphs (1) and (2) of this paragraph for wind and for runway gradients within the operational limits established by the applicant for the airplane.

(1) Not more than 50 percent of nominal wind components along the take-off path opposite to the direction of take-off, and not less than 150 percent of nominal wind components along the take-off path in the direction of take-off.

(2) Effective runway gradients.

4T.114 *Take-off speeds.*

(a) The critical-engine-failure speed V_1, in terms of calibrated air speed, shall be selected by the applicant, but shall not be less than the minimum speed at which controllability by primary aerodynamic controls alone is demonstrated during the take-off run to be adequate to permit proceeding safely with the take-off using average piloting skill, when the critical engine is suddenly made inoperative.

(b) The take-off safety speed V_2, in terms of calibrated air speed, shall be selected by the applicant so as to permit the gradient of climb required in section 4T.120 (a) and (b), but it shall not be less than:

(1) 1.2 V_s for two-engine propeller-driven airplanes and for airplanes without propellers which have no provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed;

(2) 1.15 V_s for propeller-driven airplanes having more than two engines and for airplanes without propellers which have provisions for obtaining a significant reduction in the one-engine-inoperatve power-on stalling speed;

(3) 1.10 times the minimum control speed V_{MC}, established in accordance with section 4b.133 of Part 4b of the Civil Air Regulations;

(4) The rotation speed V_R plus the increment in speed attained in compliance with section 4T.116(e).

(c) The minimum rotation speed V_R, in terms of calibrated air speed, shall be selected by the applicant, except that it shall not be less than:

(1) The speed V_1;

(2) A speed equal to 95 percent of the highest speed obtained in compliance with subparagraph (1) or (2), whichever is applicable, and with subparagraph (3) of paragraph (b) of this section;

(3) A speed which permits the attainment of the Speed V_2 prior to reaching a height of 35 feet above the take-off surface as determined in accordance with section 4T.116(e);

(4) A speed equal to 110 percent of the minimum speed above which the airplane, with all engines operating, can be made to lift off the ground and to continue the take-off without displaying any hazardous characteristics.

4T.115 *Accelerate-stop distance.*

(a) The accelerate-stop distance shall be the sum of the following:

(1) The distance required to accelerate the airplane from a standing start to the speed V_1;

(2) Assuming the critical engine to fail at the speed V_1, the distance required to bring the airplane to a full stop from the point corresponding with the speed V_1.

(b) In addition to, or in lieu of, wheel brakes, the use of other braking means shall be acceptable in determining the accelerate-stop distance, provided that such braking means shall have been proven to be safe and reliable, that the manner of their employment is such that consistent results can be expected in service, and that exceptional skill is not required to control the airplane.

(c) The landing gear shall remain extended throughout the accelerate-stop distance.

4T.116 *Take-off path.* The take-off path shall be considered to extend from the standing start to a point in the take-off where a height of 1,500 feet above the take-off surface is reached or to a point in the take-off where the transition from the take-off to the en route configuration is completed and a speed is reached at which compliance with section 4T.120(c) is shown, whichever point is at a higher altitude. The conditions of paragraphs (a) through (i) of this section shall apply in determining the take-off path.

(a) The take-off path shall be based upon procedures prescribed in accordance with section 4T.111(c).

(b) The airplane shall be accelerated on the ground to the speed V_1 at which point the critical engine shall be made inoperative and shall remain inoperative during the remainder of the take-off. Subsequent to attaining speed V_1, the airplane shall be accelerated to speed V_2 during which time it shall be permissible to initiate raising the nose gear off the ground at a speed not less than the rotation speed V_R.

(c) Landing gear retraction shall not be initiated until the airplane becomes airborne.

(d) The slope of the airborne portion of the take-off path shall be positive at all points.

(e) The airplane shall attain the speed V_2 prior to reaching a height of 35 feet above the take-off surface and shall continue at a speed as close as practical to, but not less than, V_2 until a height of 400 feet above the take-off surface is reached.

(f) Except for gear retraction and propeller feathering, the airplane configuration shall not be changed before reaching a height of 400 feet above the take-off surface.

(g) At all points along the take-off path starting at the point where the airplane first reaches a height of 400 feet above the take-off surface, the available gradient of climb shall not be less than 1.2 percent for two-engine airplanes and 1.7 percent for four-engine airplanes.

(h) The take-off path shall be determined either by a continuous demonstrated take-off, or alternatively, by synthesizing from segments the complete take-off path.

(i) If the take-off path is determined by the segmental method, the provisions of subparagraphs (1) through (4) of this paragraph shall be specifically applicable.

(1) The segments of a segmental take-off path shall be clearly defined and shall be related to the distinct changes in the configuration of the airplane, in power and/or thrust, and in speed.

(2) The weight of the airplane, the configuration, and the power and/or thrust shall be constant throughout each segment and shall correspond with the most critical condition prevailing in the particular segment.

(3) The segmental flight path shall be based on the airplane's performance without ground effect.

(4) Segmental take-off path data shall be checked by continuous demonstrated take-offs to insure that the segmental path is conservative relative to the continuous path.

4T.117 *Take-off distance and take-off run.*

(a) *Take-off distance.* The take-off distance shall be the greater of the distances established in accordance with subparagraphs (1) and (2) of this paragraph.

(1) The horizontal distance along the take-off path from the start of the take-off to the point where the airplane attains a height of 35 feet above the take-off surface, as determined in accordance with section 4T.116.

(2) A distance equal to 115 percent of the horizontal distance along the take-off path, with all engines operating, from the start of the take-off to the point where the airplane attains a height of 35 feet above the take-off surface, as determined by a procedure consistent with that established in accordance with section 4T.116.

(b) *Take-off run.* If the take-off distance is intended to include a clearway (see item 5 of this regulation), the take-off run shall be determined and shall be the greater of the distances established in accordance with subparagraphs (1) and (2) of this paragraph.

(1) The horizontal distance along the take-off path from the start of the take-off to a point equidistant between the point where the airplane first becomes airborne and the point where it attains a height of 35 feet above the take-off surface, as determined in accordance with section 4T.116.

(2) A distance equal to 115 percent of the horizontal distance along the take-off path, with all engines operating, from the start of the take-off to a point equidistant between the point where the airplane first becomes airborne and the point where it attains a height of 35 feet above the take-off surface, as determined by a procedure consistent with that established in accordance with section 4T.116.

4T.117a *Take-off flight path.*

(a) The take-off flight path shall be considered to begin at a height of 35 feet above the take-off surface at the end of the take-off distance as determined in accordance with section 4T.117(a).

(b) The net take-off flight path data shall be determined in such a manner that they represent the airplane's actual take-off flight paths, determined in accordance with paragraph (a) of this section, diminished by a gradient of climb equal to 1.0 percent.

4T.118 *Climb; general.* Compliance shall be shown with the climb requirements of sections 4T.119 and 4T.120 at all weights, altitudes, and ambient temperatures, within the operational limits established by the applicant for the airplane. The airplane's center of gravity shall be in the most unfavorable position corresponding with the applicable configuration.

4T.119 *All-engine-operating landing climb.* In the landing configuration the steady gradient of climb shall not be less than 3.2 percent, with:

(a) All engines operating at the power and/or thrust which is available 8 seconds after initiation of movement of the power and/or thrust controls from the minimum flight idle to the take-off position;

(b) A climb speed not in excess of 1.3 V_s.

4T.120 *One-engine-inoperative climb.*

(a) *Take-off; landing gear extended.* In the take-off configuration existing at the point of the flight path where the airplane first becomes airborne, in accordance with section 4T.116 but without ground effect, the steady gradient of climb shall be positive for two-engine airplanes and shall not be less than 0.5 percent for four-engine airplanes, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available take-off power and/or thrust existing in accordance with section 4T.116 at the time retraction of the airplane's landing gear is initiated, unless subsequently a more critical power operating condition exists along the flight path prior to the point where the landing gear is fully retracted;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time retraction of the airplane's landing gear is initiated;

(3) The speed equal to the speed V_2.

(b) *Take-off; landing gear retracted.* In the take-off configuration existing at the point of the flight path where the airplane's landing gear is fully retracted, in accordance with section 4T.116 but without ground effect, the steady gradient of climb shall not be less than 2.5 percent for two-engine airplanes and not less than 3.0 percent for four-engine airplanes, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available take-off power and/or thrust existing in accordance with section 4T.116 at the time the landing gear is fully retracted, unless subsequently a more critical power operating condition exists along the flight path prior to the point where a height of 400 feet above the take-off surface is reached;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time the airplane's landing gear is fully retracted;

(3) The speed equal to the speed V_2.

(c) *Final take-off.* In the en route configuration, the steady gradient of climb shall not be less than 1.2 percent for two-engine airplanes and not less than 1.7 percent for four-engine airplanes, at the end of the take-off path as determined by section 4T.116, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available maximum continuous power and/or thrust;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the end of the take-off path;

(3) The speed equal to not less than 1.25 V_s.

(d) *Approach.* In the approach configuration such that the corresponding V_s for this configuration does not exceed 110 percent of the V_s corresponding with the related landing configuration, the steady gradient of climb shall not be less than 2.2 percent for two-engine airplanes and not less than 2.7 percent for four-engine airplanes with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available take-off power and/or thrust;

(2) The weight equal to the maximum landing weight;

(3) A climb speed established by the applicant in connection with normal landing procedures, except that it shall not exceed 1.5 V_s (see sec. 4T.111(c)).

4T.121 *En route flight paths.* With the airplane in the en route configuration, the flight paths prescribed in paragraphs (a) and (b) of this section shall be determined at all weights, altitudes, and ambient temperatures within the limits established by the applicant for the airplane.

(a) *One engine inoperative.* The one-engine-inoperative net flight path data shall be determined in such a manner that they represent the airplane's actual climb performance diminished by a gradient of climb equal to 1.1 percent for two-engine airplanes and 1.6 percent for four-engine airplanes. It shall be acceptable to include in these data the variation of the airplane's weight along the flight path to take into account the progressive consumption of fuel and oil by the operating engine(s).

(b) *Two engines inoperative.* For airplanes with four engines, the two-engine-inoperative net flight path data shall be determined in such a manner that they represent the airplane's actual climb performance diminished by a gradient of climb equal to 0.5 percent. It shall be acceptable to include in these data the variation of the airplane's weight along the flight path to take into account the progressive consumption of fuel and oil by the operating engines.

(c) *Conditions.* In determining the flight paths prescribed in paragraphs (a) and (b) of this section, the conditions of subparagraphs (1) through (4) of this paragraph shall apply.

(1) The airplane's center of gravity shall be in the most unfavorable position.

(2) The critical engine(s) shall be inoperative, the remaining engine(s) operating at the available maximum continuous power and/or thrust.

(3) Means for controlling the engine cooling air supply shall be in the position which provides adequate cooling in the hot-day condition.

(4) The speed shall be selected by the applicant.

4T.122 *Landing distance.* The landing distance shall be the horizontal distance required to land and to come to a complete stop (to a speed of approximately 3 knots in the case of seaplanes or float planes) from a point at a height of 50 feet above the landing surface. Landing distances shall be determined for standard temperatures at all weights, altitudes, and winds within the operational limits established by the applicant for the airplane. The conditions of paragraphs (a) through (g) of this section shall apply.

(a) The airplane shall be in the landing configuration. During the landing, changes in the airplane's configuration, in power and/or thrust, and in speed shall be in accordance with procedures established by the applicant for the operation of the airplane in service. The procedures shall comply with the provisions of section 4T.111(c).

(b) The landing shall be preceded by a steady gliding approach down to the 50-foot height with a calibrated air speed of not less than 1.3 V_s.

(c) The landing distance shall be based on a smooth, dry, hard-surfaced runway, and shall be determined in such a manner that reproduction does not require exceptional skill or alertness on the part of the pilot. In the case of seaplanes or float planes, the landing surface shall be smooth water, while for skiplanes it shall be smooth dry snow. During landing, the airplane shall not exhibit excessive vertical acceleration, a tendency to bounce, nose over, ground loop, porpoise, or water loop.

(d) The landing distance shall be corrected for not more than 50 percent of nominal wind components along the landing path opposite to the direction of landing and not less than 150 percent of nominal wind components along the landing path in the direction of landing.

(e) During landing, the operating pressures on the wheel braking system shall not be in excess of those approved by the manufacturer of the brakes, and the wheel brakes shall not be used in such a manner as to produce excessive wear of brakes and tires.

(f) In addition to, or in lieu of, wheel brakes, the use of other braking means shall be acceptable in determining the landing distance, provided such braking means shall have been proven to be safe and reliable, that the manner of their employment is such that consistent results can be expected in service, and that exceptional skill is not required to control the airplane.

(g) If the characteristics of a device (e.g., the propellers) dependent upon the operation of any of the engines noticeably increase the landing distance when the landing is made with the engine inoperative, the landing distance shall be determined with the critical engine inoperative unless the Administrator finds that the use of compensating means will result in a landing distance not greater than that attained with all engines operating.

4T.123 *Limitations and information.*

(a) *Limitations.* The performance limitations on the operation of the airplane shall be established in accordance with subparagraphs (1) through (4) of this paragraph. (See also sec. 4T.743.)

(1) *Take-off weights.* The maximum take-off weights shall be established at which compliance is shown with the generally applicable provisions of this regulation and with the take-off climb provisions prescribed in section 4T.120 (a), (b), and (c) for altitudes and ambient temperatures within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(2) *Landing weights.* The maximum landing weights shall be established at which compliance is shown with the generally applicable provisions of this regulation and with the landing and take-off climb provisions prescribed in sections 4T.119 and 4T.120 for altitudes and ambient temperatures within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(3) *Accelerate-stop distance, take-off distance, and take-off run.* The minimum distances required for take-off shall be established at which compliance is shown with the generally applicable provisions of this regulation and with sections 4T.115 and 4T.117(a), and with 4T.117(b) if the take-off distance is intended to include a clearway, for weights, altitudes, temperatures, wind components, and runway gradients, within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(4) *Operational limits.* The operational limits of the airplane shall be established by the applicant for all variable factors required in showing compliance with this regulation (weight, altitude, temperature, etc.). (See secs. 4T.113 (a)(1) and (b), 4T.118, 4T.121, and 4T.122.)

(b) *Information.* The performance information on the operation of the airplane shall be scheduled in compliance with the generally applicable provisions of this regulation and with sections 4T.117a(b), 4T.121, and 4T.122 for weights, altitudes, temperatures, wind components, and runway gradients, as these may be applicable, within the operational limits of the airplane (see subparagraph (a)(4) of this section). In addition, the performance information specified in subparagraphs (1) through (3) of this paragraph shall be determined by extrapolation and scheduled for the ranges of weights between the maximum landing and maximum take-off weights established in accordance with subparagraphs (a)(1) and (a)(2) of this section. (See also sec. 4T.743.)

(1) Climb in the landing configuration (see sec. 4T.119);

(2) Climb in the approach configuration (see sec. 4T.120(d));

(3) Landing distance (see sec. 4T.122).

AIRPLANE FLIGHT MANUAL

4T.743 *Performance limitations, information, and other data.*

(a) *Limitations.* The airplane's performance limitations shall be given in accordance with section 4T.123(a).

(b) *Information.* The performance information prescribed in section 4T.123(b) for the application of the operating rules of this regulation shall be given together with descriptions of the conditions, air speeds, etc., under which the data were determined.

(c) *Procedures.* Procedures established in accordance with section 4T.111(c) shall be given to the extent such procedures are related to the limitations and information set forth in accordance with paragraphs (a) and (b) of this section. Such procedures, in the form of guidance material, shall be included with the relevant limitations or information, as applicable.

(d) *Miscellaneous.* An explanation shall be given of significant or unusual flight or ground handling characteristics of the airplane.

3. In lieu of sections 40.70 through 40.78, 41.27 through 41.36(d), and 42.70 through 42.83, of Parts 40, 41, and 42 of the Civil Air Regulations, respectively, the following shall be applicable:

OPERATING RULES

40T.80 *Transport category airplane operating limitations.*

(a) In operating any passenger-carrying transport category airplane certificated in accordance with the performance requirements of this regulation, the provisions of sections 40T.80 through 40T.84 shall be complied with, unless deviations therefrom are specifically authorized by the Administrator on the ground that the special circumstances of a particular case make a literal observance of the requirements unnecessary for safety.

(b) The performance data in the Airplane Flight Manual shall be applied in determining compliance with the provisions of sections 40T.81 through 40T.84. Where conditions differ from those for which specific tests were made, compliance shall be determined by approved interpolation or computation of the effects of changes in the specific variables if such interpolations or computations give results substantially equalling in accuracy the results of a direct test.

40T.81 *Airplane's certificate limitations.*

(a) No airplane shall be taken off at a weight which exceeds the take-off weight specified in the Airplane Flight Manual for the elevation of the airport and for the ambient temperature existing at the time of the take-off. (See secs. 4T.123(a)(1) and 4T.743(a).)

(b) No airplane shall be taken off at a weight such that, allowing for normal consumption of fuel and oil in flight to the airport of destination and to the alternate airports, the weight on arrival will exceed the landing weight specified in the Airplane Flight Manual for the elevation of each of the airports involved and for the ambient temperatures anticipated at the time of landing. (See secs. 4T.123(a)(2) and 4T.743(a).

(c) No airplane shall be taken off at a weight which exceeds the weight shown in the Airplane Flight Manual to correspond with the minimum distances required for take-off. These distances shall correspond with the elevation of the airport, the runway to be used, the effective runway gradient, and the ambient temperature and wind component existing at the time of take-off. (See secs. 4T.123(a)(3) and 4T.743(a).) If the take-off distance includes a clearway as defined in Item 5 of this regulation, the take-off distance shall not include a clearway distance greater than one-half of the take-off run.

(d) No airplane shall be operated outside the operational limits specified in the Airplane Flight Manual. (See secs. 4T.123(a)(4) and 42.743(a).)

40T.82 *Take-off obstacle clearance limitations.* No airplane shall be taken off at a weight in excess of that shown in the Airplane Flight Manual to correspond with a net take-off flight path which clears all obstacles either by at least a height of 35 feet vertically or by at least 200 feet horizontally within the airport boundaries and by at least 300 feet horizontally after passing beyond the boundaries. In determining the allowable deviation of the flight path in order to avoid obstacles by at least the distances prescribed, it shall be assumed that the airplane is not banked before reaching a height of 50 feet as shown by the take-off path data in the Airplane Flight Manual, and that a maximum bank thereafter does not exceed 15 degrees. The take-off path considered shall be for the elevation of the airport, the effective runway gradient, and for the ambient temperature and wind component existing at the time of take-off. (See secs. 4T.123(b) and 4T.743(b).)

40T.83 *En route limitations.*

(a) *One engine inoperative.* No airplane shall be taken off at a weight in excess of that which, according to the one-engine-inoperative en route net flight path data shown in the Airplane Flight Manual, will permit compliance with either subparagraph (1) or subparagraph (2) of this paragraph at all points along the route. The net flight path used shall be for the ambient temperatures anticipated along the route. (See secs. 4T.123(b) and 4T.743(b).)

(1) The slope of the net flight path shall be positive at an altitude of at least 1,000 feet above all terrain and obstructions along the route within 5 miles on either side of the intended track.

(2) The net flight path shall be such as to permit the airplane to continue flight from the cruising altitude to an alternate airport where a landing can be made in accordance with the provisions of section 40T.84(b), the net flight path clearing vertically by at least 2,000 feet all terrain and obstructions along the route within 5 miles on either side of the intended track. The provisions of subdivisions (i) through (vii) of this subparagraph shall apply.

(i) The engine shall be assumed to fail at the most critical point along the route.

(ii) The airplane shall be assumed to pass over the critical obstruction following engine failure at a point no closer to the critical obstruction than the nearest approved radio navigational fix, except that the Administrator may authorize a procedure established on a different basis where adequate operational safeguards are found to exist.

(iii) The net flight path shall have a positive slope at 1,500 feet above the airport used as the alternate.

(iv) An approved method shall be used to account for winds which would otherwise adversely affect the flight path.

(v) Fuel jettisoning shall be permitted if the Administrator finds that the operator has an adequate training program, proper instructions are given to the flight crew, and all other precautions are taken to insure a safe procedure.

(vi) The alternate airport shall be specified in the dispatch release and shall meet the prescribed weather minima.

(vii) The consumption of fuel and oil after the engine becomes inoperative shall be that which is accounted for in the net flight path data shown in the Airplane Flight Manual.

(b) *Two engines inoperative.* No airplane shall be flown along an intended route except in compliance with either subparagraph (1) or subparagraph (2) of this paragraph.

(1) No place along the intended track shall be more than 90 minutes away from an airport at which a landing can be made in accordance with the provisions of section 40T.84(b), assuming all engines to be operating at cruising power.

(2) No airplane shall be taken off at a weight in excess of that which, according to the two-engine-inoperative en route net flight path data shown in the Airplane Flight Manual, will permit the airplane to continue flight from the point where two engines are assumed to fail simultaneously to an airport where a landing can be made in accordance with the provisions of section 40T.84(b), the net flight path having a positive slope at an altitude of at least 1,000 feet above all terrain and obstructions along the route within 5 miles on either side of the intended track or at an altitude of 2,000 feet, whichever is higher. The net flight path considered shall be for the ambient temperatures anticipated along the route. The provisions of subdivisions (i) through (iii) of this subparagraph shall apply. (See secs. 4T.123(b) and 4T.743(b).)

(i) The two engines shall be assumed to fail at the most critical point along the route.

(ii) The airplane's weight at the point where the two engines are assumed to fail shall be considered to be not less than that which would include sufficient fuel to proceed to the airport and to arrive there at an altitude of at least 1,500 feet directly over the landing area and thereafter to fly for 15 minutes at cruise power and/or thrust.

(iii) The consumption of fuel and oil after the engines become inoperative shall be that which is accounted for in the net flight path data shown in the Airplane Flight Manual.

40T.84 *Landing limitations.*

(a) *Airport of destination.* No airplane shall be taken off at a weight in excess of that which, in accordance with the landing distances shown in the Airplane Flight Manual for the elevation of the airport of intended destination and for the wind conditions anticipated there at the time of landing, would permit the airplane to be brought to rest at the airport of intended destination within 60 percent of the effective length of the runway from a point 50 feet directly above the intersection of the obstruction clearance plane and the runway. The weight of the airplane shall be assumed to be reduced by the weight of the fuel and oil expected to be consumed in flight to the airport of intended destination. Compliance shall be shown with the conditions of subparagraphs (1) and (2) of this paragraph. (See secs. 4T.123(b) and 4T.743(b).)

(1) It shall be assumed that the airplane is landed on the most favorable runway and direction in still air.

(2) It shall be assumed that the airplane is landed on the most suitable runway considering the probable wind velocity and direction and taking due account of the ground handling characteristics of the airplane and of other conditions (i.e., landing aids, terrain, etc.). If full compliance with the provisions of this subparagraph is not shown, the airplane may be taken off if an alternate airport is designated which permits compliance with paragraph (b) of this section.

(b) *Alternate airport.* No airport shall be designated as an alternate airport in a dispatch release unless the airplane at the weight anticipated at the time of arrival at such airport can comply with the provisions of paragraph (a) of this section, provided that the airplane can be brought to rest within 70 percent of the effective length of the runway.

4. In lieu of section 43.11 of Part 43 of the Civil Air Regulations, the following shall be applicable:

43T.11 *Transport category airplane weight limitations.* The performance data in the Airplane Flight Manual shall be applied in determining compliance with the following provisions:

(a) No airplane shall be taken off at a weight which exceeds the take-off weight specified in the Airplane Flight Manual for the elevation of the airport and for the ambient temperature existing at the time of the take-off. (See secs. 4T.123(a)(1) and 4T.743(a).)

(b) No airplane shall be taken off at a weight such that, allowing for normal consumption of fuel and oil in flight to the airport of destination and to the alternate airports, the weight on arrival will exceed the landing weight specified in the Airplane Flight Manual for the elevation of each of the airports involved and for the ambient temperatures anticipated at the time of landing. (See secs. 4T.123(a)(2) and 4T.743(a).)

(c) No airplane shall be taken off at a weight which exceeds the weight shown in the Airplane Flight Manual to correspond with the minimum distances required for take-off. These distances shall correspond with the elevation of the airport, the runway to be used, the effective runway gradient, and the ambient temperature and wind component existing at the time of take-off. (See secs. 4T.123(a)(3) and 4T.743(a).) If the take-off distance includes a clearway as defined in Item 5 of this regulation, the take-off distance shall not include a clearway distance greater than one-half of the take-off run.

(d) No airplane shall be operated outside the operational limits specified in the Airplane Flight Manual. (See secs. 4T.123(a)(4) and 4T.743(a).)

5. The following definitions shall apply:

Clearway. A clearway is an area beyond the airport runway not less than 300 feet on either side of the extended center line of the runway, at an elevation no higher than the elevation at the end of the runway, clear of all fixed obstacles, and under the control of the airport authorities.

Effective: July 9, 1959
Issued: July 9, 1959

Turbine-Powered Transport Category Airplane of Current Design

Special Civil Air Regulation No. SR-422, effective August 27, 1957, prescribes requirements applicable to the type certification and operation of turbine-powered transport category airplanes for which a type certificate is issued after August 27, 1957. Special Civil Air Regulation No. SR-422A, effective July 2, 1958, included substantive changes to SR-422 and was made applicable to all turbine-powered transport category airplanes for which a type certificate is issued after September 30, 1958.

This Special Civil Air Regulation makes further changes to the airworthiness rules for turbine-powered transport category airplanes to be applicable to all such airplanes for which a type certificate is issued after August 29, 1959. These changes were proposed in Draft Release No. 58-1C (24 F.R. 128) by the Civil Aeronautics Board in connection with the 1958 Annual Airworthiness Review. The amendments herein have been adopted after careful consideration of all the discussion and comment received thereon.

Substantive and minor changes have been made to the provisions of SR-422A. For ease in identification they are listed as follows:

(a) Substantive changes: introductory paragraphs; 4T.114 (b), (c), (d), (e), and (f); 4T.115(d); 4T.117a(b); 4T.120 (a)(3), (b), and (d); 40T.81(c); 43T.11(c); and item 5 (a) and (b).

(b) Minor changes; item 2; 4T.112 (title), (b)(1), (c), (d), and (e); 4T.113(b); 4T.116(i)(4); 4T.117(b) (1) and (2); 4T.120(a); 4T.121; 4T.122(d); 4T.123(a); 40T.82; and 40T.83.

Pertinent background information to this regulation is contained in the preambles to SR-422 and SR-422A. Following is a discussion of important issues relevant to the changed provisions contained herein.

One of the most important changes being introduced concerns the rotation speed V_R of the airplane during takeoff (4T.114). Experience gained in the certification of airplanes under the provisions of SR-422 and SR-422A indicates that relating V_R to the stall speed is not essential and might unduly penalize airplanes with superior flying qualities. It has been found that the primary limitations on V_R should be in terms of a margin between the actual lift-off speeds V_{LOF} and the minimum unstick speed V_{MU} at which the airplane can proceed safely with the takeoff. The provisions contained herein require that V_R speeds be established to be applicable to takeoffs with one engine inoperative as well as with all engines operating. The V_{MU} speeds can be established from free air data provided that the data are verified by ground takeoff tests. Certain safeguards are included in conjunction with the establishment of V_R speeds to ensure that takeoffs in service can be made with consistent safety.

A change is being introduced to the provision in 4T.117a(b) concerning the manner in which the net takeoff flight path is obtained. In accordance with this provision as contained in SR–422A, the net takeoff flight path would have a negative slope throughout the acceleration segment. Since this segment usually represents level flight easily controlled by reference to the normal flight instruments, a significant reduction in the flight path's gradient would not be expected. For these reasons, the provision is being changed to permit an equivalent reduction in acceleration in lieu of a reduction in gradient.

Section 4T.117a(b) is being amended additionally by changing the value of gradient margin in the net flight path for two-engine airplanes from 1.0 percent to 0.8 percent. The value for four-engine airplanes remains 1.0 percent. Differentiation in gradient values in the net flight path between two and four-engine airplanes is consistent with the differentiation in the climb gradients for the takeoff, enroute, and approach stages of flight. Statistical analysis substantiates the specific reduction of the net flight path gradient to a value of 0.8 percent. Correlatively, a reevaluation of the climb gradients for twin-engine airplanes in the second segment takeoff and in the approach climb indicates that the respective values should be 2.4 percent and 2.1 percent and these changes are being made in 4T.120 (b) and (d).

A change is introduced in the conditions prescribed for meeting the climb gradient in the first segment takeoff climb (4T.120(a)), by changing the speed V_2 to the speed V_{LOF}. The intent of this requirement is to use the speed at which the airplane lifts off the ground. In SR–422 this speed was considered to be V_2; however, in SR–422A and in this regulation the speed V_2 is a higher speed which is reached at the end of the takeoff distance and no longer reflects the conditions pertinent to the first segment climb. In making this change consistent with relevant changes in SR–422A and in this regulation, no consideration has been given to the appropriateness of the minimum climb gradient values prescribed for the first segment climb. These are subject to alteration if results of further studies so indicate.

There is being introduced in this regulation the concept of "stopways," the definition of which is contained in item 5(b). Stopways have been used outside the United States in meeting the accelerate-stop distances in case of aborted takeoffs. They are considered to result in more practical operations. In order to ensure that they can be used without detrimental effects on safety, a provision is being included in 4T.115(d) requiring taking into account the surface characteristics of the stopways to be used in scheduling the accelerate-stop distances in the Airplane Flight Manual.

In conjunction with the introduction of stopways, there are changes being made in the definition of a "clearway" (item 5(a)). One of the changes is to specify that a clearway begins at the end of the runway whether or not a stopway is being used. Of the other changes, the most significant one expresses the clearway in terms of a clearway plane and permits this plane to have an upward slope of 1.25 percent. In effect, this change will allow, in some cases, use of clearways which would not be allowed under the definition in SR–422A because of relatively small obstacles or slightly sloping terrain. (See also 40T.81(c) and 43T.11(c).)

There are also included in this regulation a number of minor, editorial, or clarifying changes.

Draft Release No. 58-1C included a proposal for expanding lateral obstacle clearances in the takeoff flight path. Studies indicate that some expanding lateral clearances are necessary for safety in operations with all turbine-powered airplanes. It appears, therefore, that an appropriate rule should be made applicable not only to airplanes certificated in accordance with this regulation, but also to those certificated in accordance with SR-422 and SR-422A. Accordingly, no change is being made in this regulation to the lateral obstacle clearance provisions, instead, a Notice of Proposed Rule Making is now being prepared to amend SR-422, SR-422A, and this regulation, to require expanding lateral obstacle clearances for all airplanes certificated thereunder.

This Special Civil Air Regulation is not intended to compromise the authority of the Administrator under section 4b.10 to impose such special conditions as are found necessary in any particular case to avoid unsafe design features and otherwise to ensure equivalent safety.

Interested persons have been afforded an opportunity to participate in the making of this regulation (24 F.R. 128), and due consideration has been given to all relevant matter presented.

This regulation does not require compliance until after August 29, 1959; however, since applicants for a type certificate for turbine-powered transport category airplanes may elect to show compliance with this regulation before that date, it is being made effective immediately.

In consideration of the foregoing, the following Special Civil Air Regulation is hereby promulgated to become effective immediately:

Contrary provisions of the Civil Air Regulations notwithstanding, all turbine-powered transport category airplanes for which a type certificate is issued after August 29, 1959, shall comply with the following requirements. Applicants for a type certificate for a turbine-powered transport category airplane may elect and are authorized to meet the requirements of this Special Civil Air Regulation prior to August 29, 1959, in which case however, all of the following provisions must be complied with.

1. The provisions of Part 4b of the Civil Air Regulations, effective on the date of application for type certificate; and such of the provisions of all subsequent amendments to Part 4b, in effect prior to August 27, 1957, as the Administator finds necessary to ensure that the level of safety of turbine-powered airplanes is equivalent to that generally intended by Part 4b.

2. In lieu of sections 4b. 110 through 4b.125, 4b.183, and 4b.743 of Part 4b of the Civil Air Regulations, the following shall be applicable:

PERFORMANCE

4T.110 *General.*

(a) The performance of the airplane shall be determined and scheduled in accordance with, and shall meet the minima prescribed by, the provision of sections 4T.110 through 4T.123. The performance limitations, information, and other data shall be given in accordance with section 4T.743.

(b) Unless otherwise specifically prescribed, the performance shall correspond with ambient atmospheric conditions and still air.

Humidity shall be accounted for as specified in paragraph (c) of this section.

(c) The performance as affected by engine power and/or thrust shall be based on a relative humidity of 80 percent at and below standard temperatures and on 34 percent at and above standard temperatures plus 50° F. Between these two temperatures the relative humidity shall vary linearly.

(d) The performance shall correspond with the propulsive thrust available under the particular ambient atmospheric conditions, the particular flight condition, and the relative humidity specified in paragraph (c) of this section. The available propulsive thrust shall correspond with engine power and or thrust not exceeding the approved power and or thrust less the installational losses and less the power and or equivalent thrust absorbed by the accessories and services appropriate to the particular ambient atmospheric conditions and the particular flight condition.

4T.111 *Airplane configuration, speed, power, and/or thrust; general.*

(a) The airplane configuration (setting of wing and cowl flaps, air brakes, landing gear, propeller, etc.), denoted respectively as the takeoff, en route, approach, and landing configurations, shall be selected by the applicant except as otherwise prescribed.

(b) It shall be acceptable to make the airplane configurations variable with weight, altitude, and temperature, to an extent found by the Administrator to be compatible with operating procedures required in accordance with paragraph (c) of this section.

(c) In determining the accelerate-stop distances, takeoff flight paths, takeoff distances, and landing distances, changes in the airplane's configuration and speed, and in the power and thrust shall be in accordance with procedures established by the applicant for the operation of the airplane in service, except as otherwise prescribed. In addition, procedures shall be established for the execution of balked landings and missed approaches associated with the conditions prescribed in sections 4T.119 and 4T.120(d), respectively. All procedures shall comply with the pro isions of subparagraphs (1) through (3) of this paragraph.

(1) The Administrator shall find that the procedures can be consistently executed in service by crews of average skill.

(2) The procedures shall not involve methods or the use of devices which have not been proven to be safe and reliable.

(3) Allowance shall be made for such time delays in the execution of the procedures as may be reasonably expected to occur during service.

4T.112 *Stalling and minimum control speeds.*

(a) The speed V_s shall denote the calibrated stilling speed, or the minimum steady flight speed at which the airplane is controllable, in knots, with:

(1) Zero thrust at the stalling speed, or engines idling and throttles closed if it is shown that the resultant thrust has no appreciable effect on the stalling speed;

(2) If applicable, propeller pitch controls in the position

necessary for compliance with subparagraph (1) of this paragraph; the airplane in all other respects (flaps, landing gear, etc.) in the particular configuration corresponding with that in connection with which V_s is being used;

(3) The weight of the airplane equal to the weight in connection with which V_s is being used to determine compliance with a particular requirement;

(4) The center of gravity in the most unfavorable position within the the allowable range.

(b) The stall speed defined in this section shall be the minimum speed obtained in flight tests conducted in accordance with the procedure of subparagraphs (1) and (2) of this paragraph.

(1) With the airplane trimmed for straight flight at a speed chosen by the applicant, but not less than 1.2 V_s nor greater than 1.4 V_s, and from a speed sufficiently above the stalling speed to ensure steady conditions, the elevator control shall be applied at a rate such that the airplane speed reduction does not exceed 1 knot per second.

(2) During the test prescribed in subparagraph (1) of this paragraph, the flight characteristics provisions of section 4b.160 of Part 4b of the Civil Air Regulations shall be complied with.

(c) The minimum control speed V_{MC}, in terms of calibrated air speeed, shall be determined under the conditions specified in this paragraph so that, when the critical engine is suddenly made inoperative at that speed, it is possible to recover control of the airplane with the engine still inoperative and to maintain it in straight flight at that speed, either with zero yaw or, at the option of the applicant, with an angle of bank not in excess of 5 degrees. V_{MC} shall not exceed 1.2 V_s with:

(1) Engines operating at the maximum available takeoff thrust and/or power;

(2) Maximum sea level takeoff weight or such lesser weight as might be necessary to demonstrate V_{MC}.

(3) The airplane in the most critical takeoff configuration existing along the flight path after the airplane becomes airborne, except that the landing gear is retracted;

(4) The airplane trimmed for takeoff;

(5) The airplane airborne and the ground effect negligible;

(6) The center of gravity in the most unfavorable position;

(d) In demonstrating the minimum speed specified in paragraph (c) of this section, the rudder force required to maintain control shall not exceed 180 pounds and it shall not be necessary to reduce the power and/or thrust of the operative engine(s).

(e) During recovery from the maneuver specified in paragraph (c) of this section, the airplane shall not assume any dangerous attitude, nor shall it require exceptional skill, strength, or alertness on the part of the pilot to prevent a change of heading in excess of 20 degrees before recovery is complete.

4T.113 *Takeoff; general.*

(a) The takeoff data in sections 4T.114 through 4T.117 shall be determined under the conditions of subparagraphs (1) and (2) of this paragraph.

(1) At all weights, altitudes, and ambient temperatures, within the operational limits established by the applicant for the airplane.

(2) In the configuration for takeoff (see sec. 4T.111).

(b) Takeoff data shall be based on a smooth, dry, hard-surfaced runway and shall be determined in such a manner that reproduction of the performance does not require exceptional skill or alertness on the part of the pilot. In the case of seaplanes or float planes, the takeoff surface shall be smooth water, while for skiplane it shall be smooth, dry snow. In addition. the takeoff data shall include operational correction factors in accordance with subparagraphs (1) and (2) of this paragraph for wind and for runway gradients, within the operational limits established by the applicant for the airplane.

(1) Not more than 50 percent of nominal wind components along the takeoff path opposite to the direction of takeoff, and not less than 150 percent of nominal wind components along the takeoff path in the direction of takeoff.

(2) Effective runway gradients.

4T.114 *Takeoff speeds.*

(a) The critical-engine-failure speed V_1 in terms of calibrated air speed, shall be selected by the applicant, but shall not be less than the minimum speed at which controllability by primary aerodynamic controls alone is demonstrated during the takeoff run to be adequate to permit proceeding safely with the takeoff using average piloting skill, when the critical engine is suddenly made inoperative.

(b) The minimum takeoff safety speed $V_{2\,min}$, in terms of calibrated air speed, shall not be less than:

(1) 1.2 V_s for two-engine propeller-driven airplanes and for airplanes without propellers which have no provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed;

(2) 1.15 V_s for propeller-driven airplanes having more than two engines and for airplanes without propellers which have provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed;

(3) 1.10 times the minimum control speed V_{MC}.

(c) The takeoff safety speed V_2, in terms of calibrated air speed, shall be selected by the applicant so as to permit the gradient of climb required in section 4T.120(b), but it shall not be less than:

(1) The speed $V_{2\,min}$,

(2) The rotation speed V_R (see paragraph (e) of this section) plus the increment in speed attained prior to reaching a height of 35 feet above the takeoff surface in compliance with section 4T.116(e).

(d) The minimum unstick speed V_{MU}, in terms of calibrated air speed, shall be the speed at and above which the airplane can be made to lift off the ground and to continue the takeoff without displaying any hazardous characteristics. V_{MU} speeds shall be selected by the applicant for the all-engines-operating and the one-engine-inoperative conditions. It shall be acceptable to establish the V_{MU} speeds from free air data: *Provided*, That these data are verified by ground takeoff tests.

NOTE: In certain cases, ground takeoff tests might involve some takeoffs at the V_{MU} speeds.

(e) The rotation speed V_R, in terms of calibrated air speed, shall be selected by the applicant in compliance with the conditions of subparagraphs (1) through (4) of this paragraph.

(1) The V_R speed shall not be less than:

(i) The speed V_1;

(ii) A speed equal to 105 percent of V_{MC};

(iii) A speed which permits the attainment of the speed V_2 prior to reaching a height of 35 feet above the takeoff surface as determined in accordance with section 4T.116(e);

(iv) A speed which, if the airplane is rotated at its maximum practicable rate, will result in a lift-off speed V_{LOF} (see paragraph (f) of this section) not less than 110 percent of V_{MC} in the all-engines-operating condition nor less than 105 percent of V_{MC} in the one-engine-inoperative condition.

(2) For any given set of conditions (weight, configuration, temperature, etc.), a single value of V_R speed obtained in accordance with this paragraph shall be used in showing compliance with both the one-engine-inoperative and the all-engines-operating takeoff provisions.

(3) It shall be shown that the one-engine-inoperative takeoff distance determined with a rotation speed 5 knots less than the V_R speed established in accordance with subparagraphs (1) and (2) of this paragraph does not exceed the corresponding one-engine-inoperative takeoff distance determined with the established V_R speed. The determination of the takeoff distances shall be in accordance with section 4T.117(a)(1).

(4) It shall be demonstrated that reasonably expected variations in service from the takeoff procedures established by the applicant for the operation of the airplane (see sec. 4T.111(c)) (e.g., over-rotation of the airplane, out of trim conditions) will not result in unsafe flight characteristics nor in marked increases in the scheduled takeoff distances established in accordance with section 4T.117(a).

(f) The lift-off speed V_{LOF}, in terms of calibrated air speed, shall be the speed at which the airplane first becomes airborne.

4T.115 *Accelerate-stop distance.*

(a) The accelerate-stop distance shall be the sum of the following:

(1) The distance required to accelerate the airplane from a standing start to the speed V_1;

(2) Assuming the critical engine to fail at the speed V_1, the distance required to bring the airplane to a full stop from the point corresponding with the speed V_1.

(b) In addition to, or in lieu of, wheel brakes, the use of other braking means shall be acceptable in determining the accelerate-stop distance, provided that such braking means shall have been proven to be safe and reliable, that the manner of their employment is such that consistent results can be expected in service and that exceptional skill is not required to control the airplane.

(c) The landing gear shall remain extended throughout the accelerate-stop distance.

(d) If the accelerate-stop distance is intended to include a stopway with surface characteristics substantially different from those of a smooth hard-surfaced runway, the takeoff data shall include operational correction factors for the accelerate-stop distance to account for the particular surface characteristics of the stopway and the variations in such characteristics with seasonal weather conditions (i.e., temperature, rain, snow, ice, etc.), within the operational limits established by the applicant.

4T.116 *Takeoff path.* The takeoff path shall be considered to extend from the standing start to a point in the takeoff where a height of 1,500 feet above the takeoff surface is reached or to a point in the takeoff where the transition from the takeoff to the en route configuration is completed and a speed is reached at which compliance with section 4T.120(c) is shown, whichever point is at a higher altitude. The conditions of paragraphs (a) through (i) of this section shall apply in determining the takeoff path.

(a) The takeoff path shall be based upon procedures prescribed in accordance with section 4T.111(c).

(b) The airplane shall be accelerated on the ground to the speed V_1 at which point the critical engine shall be made inoperative and shall remain inoperative during the remainder of the takeoff. Subsequent to attaining speed V_1, the airplane shall be accelerated to speed V_2 during which time it shall be permissible to initiate raising the nose gear off the

(c) Landing gear retraction shall not be initiated until the
ground at a speed not less than the rotating speed V_R.
airplane becomes airborne.

(d) The slope of the airborne portion of the takeoff path shall be positive at all points.

(e) The airplane shall attain the speed V_2 prior to reaching a height of 35 feet above the takeoff surface and shall continue at a speed as close as practical to, but not less than, V_2 until a height of 400 feet above the takeoff surface is reached.

(f) Except for gear retraction and propeller feathering, the airplane configuration shall not be changed before reaching a height of 400 feet above the takeoff surface.

(g) At all points along the takeoff path starting at the point where the airplane first reaches a height of 400 feet above the takeoff surface, the available gradient of climb shall not be less than 1.2 percent for two-engine airplanes, and 1.7 percent for four-engine airplanes.

(h) The takeoff path shall be determined either by a continuous demonstrated takeoff, or alternatively, by synthesizing from segments the complete takeoff path.

(i) If the takeoff path is determined by the segmental method, the provisions of subparagraphs (1) through (4) of this paragraph shall be specifically applicable.

(1) The segments of a segmental takeoff path shall be clearly defined and shall be related to the distinct changes in the configuration of the airplane, in power and/or thrust, and in speed.

(2) The weight of the airplane, the configuration, and the power and/or thrust shall be constant throughout each segment and shall correspond with the most critical condition prevailing in the particular segment.

(3) The segmental flight path shall be based on the airplane's performance without ground effect.

(4) Segmental takeoff path data shall be checked by continuous demonstrated takeoffs up to the point where the airplane's performance is out of ground effect and the airplane's speed is stabilized, to ensure that the segmental path is conservative relative to the continuous path.

NOTE: The airplane usually is considered out of ground effect when it reaches a height above the ground equal to the airplane's wing span.

4T.117 *Takeoff distance and takeoff run.*

(a) *Takeoff distance.* The takeoff distance shall be the greater of the distances established in accordance with subparagraphs (1) and (2) of this paragraph.

(1) The horizontal distance along the takeoff path from the start of the takeoff to the point where the airplane attains a height of 35 feet above the takeoff surface, as determined in accordance with section 4T.116.

(2) A distance equal to 115 percent of the horizontal distance along the takeoff path, with all engines operating, from the start of the takeoff to the point where the airplane attains a height of 35 feet above the takeoff surface, as determined by a procedure consistent with that established in accordance with section 4T.116.

(b) *Takeoff run.* If the takeoff distance is intended to include a clearway (see item 5 of this regulation), the takeoff run shall be determined and shall be the greater of the distances established in accordance with subparagraphs (1) and (2) of this paragraph.

(1) The horizontal distance along the takeoff path from the start of the takeoff to a point equidistant between the point where the speed V_{LOF} is reached and the point where the airplane attains a height of 35 feet above the takeoff surface, as determined in accordance with section 4T.116.

(2) A distance equal to 115 percent of the horizontal distance along the takeoff path, with all engines operating, from the start of the takeoff to a point equidistant between the point where the speed V_{LOF} is reached and the point where the airplane attains a height of 35 feet above the takeoff surface, as determined by a procedure consistent with that established in accordance with section 4T.116.

4T.117a *Takeoff flight path.*

(a) The takeoff flight path shall be considered to begin at a height of 35 feet above the takeoff surface at the end of the takeoff distance as determined in accordance with section 4T.117(a).

(b) The net takeoff flight path data shall be determined in such a manner that they represent the airplane's actual takeoff flight paths, determined in accordance with section 4T.116 and with paragraph (a) of this section, reduced at each point by a gradient of climb equal to 0.8 percent for two-engine airplanes and equal to 1.0 percent for four-engine airplanes. It shall be acceptable to apply the prescribed reduction in climb gradient as an equivalent reduction in the airplane's acceleration along that portion of the actual takeoff flight path where the airplane is accelerated in level flight.

4T.118 *Climb; general.* Compliance shall be shown with the climb requirements of sections 4T.119 and 4T.120 at all weights, altitudes, and ambient temperatures, within the operational limits established by the applicant for the airplane. The airplane's center of gravity shall be in the most unfavorable position corresponding with the applicable configuration.

4T.119 *All-engine-operating landing climb.* In the landing configuration the steady gradient of climb shall not be less than 3.2 percent, with:

(a) All engines operating at the power and/or thrust which are available 8 seconds after initiation of movement of the power and/or thrust controls fromthe minimum flight idle to the takeoff position;

(b) A climb speed not in excess of 1.3 V_s.

4T.120 *One-engine-inoperative climb.*

(a) *Takeoff; landing gear extended.* In the critical takeoff configuration existing along the flight path between the points where the airplane reaches the speed V_{LOF} and where the landing gear is fully retracted, in accordance with section 4T.116 but without ground effect, the steady gradient of climb shall be positive for two-engine airplanes and shall not be less than 0.5 percent for four-engine airplanes, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available takeoff power and/or thrust existing in accordance with section 4T.116 at the time retraction of the airplane's landing gear is initiated, unless subsequently a more critical power operating condition exists along the flight path prior to the point where the landing gear is fully retracted;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time retraction of the airplane's landing gear is initiated;

(3) The speed equal to the speed V_{LOF}.

(b) *Takeoff; landing gear retracted.* In the takeoff configuration existing at the point of the flight path where the airplane's landing gear is fully retracted, in accordance with section 4T.116 but without ground effect, the steady gradient of climb shall not be less than 2.4 percent for two-engine airplanes and not less than 3.0 percent for four-engine airplanes, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available takeoff power and/or thrust existing in accordance with section 4T.116 at the time the landing gear is fully retracted, unless subsequently a more critical power operating condition exists along the flight path prior to the point where a height of 400 feet above the takeoff surface is reached;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time the airplane's landing gear is fully retracted;

(3) The speed equal to the speed V_2.

(c) *Final takeoff.* In the en route configuration, the steady gradient of climb shall not be less than 1.2 percent for two-engine airplanes and not less than 1.7 percent for four-engine airplanes, at the end of the takeoff path as determined by section 4T.116, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available maximum continuous power and/or thrust;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the end of the takeoff path.

(3) The speed equal to not less than 1.25 V_s.

(d) *Approach.* In the approach configuration corresponding with the normal all-engines-operating procedure such that V_s related to this configuration does not exceed 110 percent of the V_s corresponding with the related landing configuration, the steady gradient of climb shall not be less than 2.1 percent for two-engine airplanes and not less than 2.7 percent for four-engine airplanes with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available takeoff power and/or thrust;

(2) The weight equal to the maximum landing weight;

(3) A climb speed established by the applicant in connection with normal landing procedures, except that it shall not exceed 1.5 V_s (see sec. 4T.111(c)).

4T.121 *En route flight paths.* With the airplane in the en route configuration, the flight paths prescribed in paragraphs (a) and (b) of this section shall be determined at all weights, altitudes, and ambient temperatures, within the operational limits established by the applicant for the airplane.

(a) *One engine inoperative.* The one-engine-inoperative net flight path data shall be determined in such a manner that they represent the airplane's actual climb performance diminished by a gradient of climb equal to 1.1 percent for two-engine airplanes and 1.6 percent for four-engine airplanes. It shall be acceptable to include in these data the variation of the airplane's weight along the flight path to take into account the progressive consumption of fuel and oil by the operating engine(s).

(b) *Two engines inoperative.* For airplanes with four engines, the two-engine-inoperative net flight path data shall be determined in such a manner that they represent the airplane's actual climb performance diminished by a gradient of climb equal to 0.5 percent. It shall be acceptable to include in these data the variation of the airplane's weight along the flight path to take into account the progressive consumption of fuel and oil by the operating engines.

(c) *Conditions.* In determining the flight paths prescribed in paragraphs (a) and (b) of this section, the conditions of subparagraphs (1) through (4) of this paragraph shall apply.

(1) The airplane's center of gravity shall be in the most unfavorable position.

(2) The critical engine(s) shall be inoperative, the remaining engine(s) operating at the available maximum continuous power and/or thrust.

(3) Means for controlling the engine cooling air supply shall be in the position which provides adequate cooling in the hot-day condition.

(4) The speed shall be selected by the applicant.

4T.122 *Landing distance.* The landing distance shall be the horizontal distance required to land and to come to a complete stop (to a speed of approximately 3 knots in the case of seaplanes or float planes) from a point at a height of 50 feet above the landing surface. Landing distances shall be determined for standard temperatures at all weights, altitudes, and winds, within the operational limits established by the applicant for the airplane. The conditions of paragraphs (a) through (g) of this section shall apply.

(a) The airplane shall be in the landing configuration. During the landing, changes in the airplane's configuration, in power and/or thrust, and in speed shall be in accordance with procedures established by the applicant for the operation of the airplane in service. The procedures shall comply with the provisions of section 4T.111(c).

(b) The landing shall be preceded by a steady gliding approach down to the 50-foot height with a calibrated air speed of not less than 1.3 V_s.

(c) The landing distance shall be based on a smooth, dry, hard-surfaced runway, and shall be determined in such a manner that reproduction does not require exceptional skill or alertness on the part of the pilot. In the case of seaplanes or float planes, the landing surface shall be smooth water, while for skiplanes it shall be smooth, dry snow. During landing, the airplane shall not exhibit excessive vertical acceleration, a tendency to bounce, nose over, ground loop, porpoise, or water loop.

(d) The landing distance data shall include operational correction factors for not more than 50 percent of nominal wind components along the landing path opposite to the direction of landing and not less than 150 percent of nominal wind components along the landing path in the direction of landing.

(e) During landing, the operating pressures on the wheel braking system shall not be in excess of those approved by the manufacturer of the brakes, and the wheel brakes shall not be used in such a manner as to produce excessive wear of brakes and tires.

(f) In addition to, or in lieu, of, wheel brakes, the use of other braking means shall be acceptable in determining the landing distance, provided such braking means shall have been proven to be safe and reliable, that the manner of their employment is such that consistent results can be expected in service, and that exceptional skill is not required to control the airplane.

(g) If the characteristics of a device (e.g., the propellers) dependent upon the operation of any of the engines noticeably increase the landing distance when the landing is made with the engine inoperative, the landing distance shall be determined with the critical engine inoperative unless the Administrator finds that the use of compensating means will result in a landing distance not greater than that attained with all engines operating.

4T.123 *Limitations and information.*

(a) *Limitations.* The performance limitations on the operation of the airplane shall be established in accordance with subparagraph (1) through (4) of this paragraph. (See also sec. 4T.743.)

(1) *Takeoff weights.* The maximum takeoff weights shall be established at which compliance is shown with the generally applicable provisions of this regulation and with the takeoff climb provisions pre-

scribed in section 4T.120 (a), (b), and (c) for altitudes and ambient temperatures, within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(2) *Landing weights.* The maximum landing weights shall be established at which compliance is shown with the generally applicable provisions of this regulation and with the landing and takeoff climb provisions prescribed in sections 4T.119 and 4T.120 for altitudes and ambient temperatures, within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(3) *Accelerate-stop distance, takeoff distance, and takeoff run.* The minimum distances required for takeoff shall be established at which compliance is shown with the generally applicable provisions of this regulation and with sections 4T.115 and 4T.117(a) and with 4T.117(b) if the takeoff distance is intended to include a clearway, for weights, altitudes, temperatures, wind components, and runway gradients, within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(4) *Operational limits.* The operational limits of the airplane shall be established by the applicant for all variable factors required in showing compliance with this regulation (weight, altitude, temperature, etc.). (See secs. 4T.113 (a)(1) and (b), 4T.115(d), 4T.118, 4T.121, and 4T.122.)

(b) *Information.* The performance information on the operation of the airplane shall be scheduled in compliance with the generally applicable provisions of this regulation and with sections 4T.117a(b), 4T.121, and 4T.122 for weights, altitudes, temperatures, wind components, and runway gradients, as these may be applicable, within the operational limits of the airplane (see subparagraph (a)(4) of this section). In addition, the performance information specified in subparagraphs (1) through (3) of this paragraph shall be determined by extrapolation and scheduled for the ranges of weights between the maximum landing and maximum takeoff weights established in accordance with subparagraphs (a)(1) and (a)(2) of this section. (See also sec. 4T.743.)

(1) Climb in the landing configuration (see sec. 4T.119);
(2) Climb in the approach configuration (see sec. 4T.120(d));
(3) Landing distance (see sec. 4T.122).

AIRPLANE FLIGHT MANUAL

4T.743 *Performance limitations, information, and other data.*

(a) *Limitations.* The airplane's performance limitations shall be given in accordance with section 4T.123(a).

(b) *Information.* The performance information prescribed in section 4T.123(b) for the application of the operating rules of this regulation shall be given together with descriptions of the conditions, air speeds, etc., under which the data were determined.

(c) *Procedures.* Procedures established in accordance with section 4T.111(c) shall be given to the extent such procedures are related to the limitations and information set forth in accordance with paragraphs (a) and (b) of this section. Such procedures, in the form of guidance material, shall be included with the relevant limitations or information, as applicable.

(d) *Miscellaneous.* An explanation shall be given of significant or unusual flight or ground handling characteristics of the airplane.

3. In lieu of sections 40.70 through 40.78, 41.27 through 41.36(d), and 42.70 through 42.83, of Parts 40, 41, and 42, respectively, of the Civil Air Regulations, the following shall be applicable:

OPERATING RULES

40T.80 *Transport category airplane operating limitations.*

(a) In operating any passenger-carrying transport category airplane certificated in accordance with the performance requirements of this regulation, the provisions of sections 40T.80 through 40T.84 shall be complied with, unless deviations therefrom are specifically authorized by the Administrator on the ground that the special circumstances of a particular case make a literal observance of the requirements unnecessary for safety.

(b) The performance data in the Airplane Flight Manual shall be applied in determining compliance with the provisions of sections 40T.81 through 40T.84. Where conditions differ from those for which specific tests were made, compliance shall be determined by approved interpolation or computation of the effects of changes in the specific variables if such interpolations or computations give results substantially equalling in accuracy the results of a direct test.

40T.81 *Airplane's certificate limitations.*

(a) No airplane shall be taken off at a weight which exceeds the takeoff weight specified in the Airplane Flight Manual for the elevation of the airport and for the ambient temperature existing at the time of the takeoff. (See secs. 4T.123(a)(1) and 4T.743(a).)

(b) No airplane shall be taken off at a weight such that, allowing for normal consumption of fuel and oil in flight to the airport of destination and to the alternate airports, the weight on arrival will exceed the landing weight specified in the Airplane Flight Manual for the elevation of each of the airports involved and for the ambient temperatures anticipated at the time of landing. (See secs. 4T.123(a)(2) and 4T.743(a).)

(c) No airplane shall be taken off at a weight which exceeds the weight at which, in accordance with the minimum distances for takeoff scheduled in the Airplane Flight Manual, compliance with subparagraphs (1) through (3) of this paragraph is shown. These distances shall correspond with the elevation of the airport, the runway to be used, the effective runway gradient, and the ambient temperature and wind component existing at the time of takeoff. (See secs. 4T.123(a)(3) and 4T.743(a).)

(1) The accelerate-stop distance shall not be greater than the length of the runway plus the length of the stopway if present.

(2) The takeoff distance shall not be greater than the length of the runway plus the length of the clearway if present, except that the length of the clearway shall not be greater than one-half of the length of the runway.

(3) The takeoff run shall not be greater than the length of the runway.

(d) No airplane shall be operated outside the operational limits specified in the Airplane Flight Manual. (See secs. 4T.123(a)(4) and 4T.743(a).)

40T.82 *Takeoff obstacle clearance limitations.* No airplane shall be taken off at a weight in excess of that shown in the Airplane Flight Manual to correspond with a net takeoff flight path which clears all obstacles either by at least a height of 35 feet vertically or by at least 200 feet horizontally within the airport boundaries and by at least 300 feet horizontally after passing beyond the boundaries. In determining the allowable deviation of the net takeoff flight path in order to avoid obstacles by at least the distances prescribed, it shall be assumed that the airplane is not banked before reaching a height of 50 feet as shown by the net takeoff flight path data in the Airplane Flight Manual, and that a maximum bank thereafter does not exceed 15 degrees. The net takeoff flight path considered shall be for the elevation of the airport, the effective runway gradient, and for the ambient temperature and wind component existing at the time of takeoff. (See secs. 4T.123(b) and 4T.743(b).)

40T.83 *En route limitations.* All airplanes shall be operated in compliance with paragraph (a) of this section. In addition, no airplane shall be flown along an intended route if any place along the route is more than 90 minutes away from an airport at which a landing can be made in accordance with section 40T.84(b), assuming all engines to be operating at cruising power, unless compliance is shown with paragraph (b) of this section.

(a) *One engine inoperative.* No airplane shall be taken off at a weight in excess of that which, according to the one-engine-inoperative en route net flight path data shown in the Airplane Flight Manual, will permit compliance with either subparagraphs (1) or (2) of this paragraph at all points along the route. The net flight path shall have a positive slope at 1,500 feet above the airport where the landing is assumed to be made after the engine fails. The net flight path used shall be for the ambient temperatures anticipated along the route. (See secs. 4T.123(b) and 4T.743(b).)

(1) The slope of the net flight path shall be positive at an altitude of at least 1,000 feet above all terrain and obstructions along the route within 5 statute miles (4.34 nautical miles) on either side of the intended track.

(2) The net flight path shall be such as to permit the airplane to continue flight from the cruising altitude to an airport where a landing can be made in accordance with the provisions of section 40T.84(b), the net flight path clearing vertically by at least 2,000 feet all terrain and obstructions along the route within 5 statute miles (4.34 nautical miles) on either side of the intended track. The provisions of subdivisions (i) through (vi) of this subparagraph shall apply.

(i) The engine shall be assumed to fail at the most critical point along the route.

(ii) The airplane shall be assumed to pass over the critical obstruction following engine failure at a point no closer to the critical obstruction than the nearest approved radio navigational fix, except that the Administrator may authorize a procedure established on a different basis where adequate operational safeguards are found to exist.

(iii) An approved method shall be used to account for winds which would otherwise adversely affect the flight path.

(iv) Fuel jettisoning shall be permitted if the Administrator finds that the operator has an adequate training program, proper instructions are given to the flight crew, and all other precautions are taken to ensure a safe procedure.

(v) The alternate airport shall be specified in the dispatch release and shall meet the prescribed weather minima.

(vi) The consumption of fuel and oil after the engine is assumed to fail shall be that which is accounted for in the net flight path data shown in the Airplane Flight Manual.

(b) *Two engines inoperative.* No airplane shall be taken off at a weight in excess of that which, according to the two-engine-inoperative en route net flight path data shown in the Airplane Flight Manual, will permit the airplane to continue flight from the point where two engines are assumed to fail simultaneously to an airport where a landing can be made in accordance with the provisions of section 40T.84(b), the net flight path clearing vertically by at least 2,000 feet all terrain and obstructions along the route within 5 statute miles (4.34 nautical miles) on either side of the intended track. The net flight path considered shall be for the ambient temperatures anticipated along the route. The provisions of subparagraphs (1) through (5) of this paragraph shall apply. (See secs. 4T.123(b) and 4T.734(b).)

(1) The two engines shall be assumed to fail at the most critical point along the route.

(2) The net flight path shall have a positive slope at 1,500 feet above the airport where the landing is assumed to be made after failure of two engines.

(3) Fuel jettisoning shall be permitted if the Administrator finds that the operator has an adequate training program, proper instructions are given to the flight crew, and all other precautions are taken to ensure a safe procedure.

(4) The airplane's weight at the point where the two engines are assumed to fail shall be considered to be not less than that which would include sufficient fuel to proceed to the airport and to arrive there at an altitude of at least 1,500 feet directly over the landing area and thereafter to fly for 15 minutes at cruise power and/or thrust.

(5) The consumption of fuel and oil after the engines are assumed to fail shall be that which is accounted for in the net flight path data shown in the Airplane Flight Manual.

40T.84 *Landing limitations.*

(a) *Airport of destination.* No airplane shall be taken off at a weight in excess of that which, in accordance with the landing distances shown in the Airplane Flight Manual for the elevation of the airport of intended destination and for the wind conditions anticipated there at the time of landing, would permit the airplane to be brought to rest at the airport of intended destination within 60 percent of the effective length of the runway from a point 50 feet directly above the intersection of the obstruction clearance plane and the runway. The weight of the airplane shall be assumed to be reduced by the weight of the fuel and oil expected to be consumed in flight to the airport of intended destination. Compliance shall be shown with the conditions of subparagraphs (1) and (2) of this paragraph. (See secs. 4T.123(b) and 4T.743(b).)

(1) It shall be assumed that the airplane is landed on the most favorable runway and direction in still air.

(2) It shall be assumed that the airplane is landed on the most suitable runway considering the probable wind velocity and direction and taking due account of the ground handling characteristics of the airplane and of other conditions (i.e., landing aids, terrain, etc.). If full compliance with the provisions of this subparagraph is not shown, the airplane may be taken off if an alternate airport is designated which permits compliance with paragraph (b) of this section.

(b) *Alternate airport.* No airport shall be designated as an alternate airport in a dispatch release unless the airplane at the weight anticipated at the time of arrival at such airport can comply with the provisions of paragraph (a) of this section, provided that the airplane can be brought to rest within 70 percent of the effective length of the runway.

4. In lieu of section 43.11 of Part 43 of the Civil Air Regulations the following shall be applicable.

43T.11 *Transport category airplane weight limitations.* The performance data in the Airplane Flight Manual shall be applied in determining compliance with the following provisions:

(a) No airplane shall be taken off at a weight which exceeds the takeoff weight specified in the Airplane Flight Manual for the elevation of the airport and for the ambient temperature existing at the time of the takeoff. (See secs. 4T.123(a)(1) and 4T.743(a).)

(b) No airplane shall be taken off at a weight such that, allowing for normal consumption of fuel and oil in flight to the airport of destination and to the alternate airports, the weight on arrival will exceed the landing weight specified in the Airplane Flight Manual for the elevation of each of the airports involved and for the ambient temperatures anticipated at the time of landing. (See secs. 4T.123(a)(2) and 4T.743(a).)

(c) No airplane shall be taken off at a weight which exceeds the weight at which, in accordance with the minimum distances for takeoff scheduled in the Airplane Flight Manual, compliance with subparagraphs (1) through (3) of this paragraph is shown. These distances shall correspond with the elevation of the airport, the runway to be used, the effective runway gradient, and the ambient temperature and wind component existing at the time of takeoff. (See secs. 4T.123(a)(3) and 4T.734(a).)

(1) The accelerate-stop distance shall not be greater than the length of the runway plus the length of the stopway if present.

(2) The takeoff distance shall not be greater than the length of the runway plus the length of the clearway if present, except that the length of the clearway shall not be greater than one-half of the length of the runway.

(3) The takeoff run shall not be greater than the length of the runway.

(d) No airplane shall be operated outside the operational limits specified in the Airplane Flight Manual. (See secs. 4T.123(a)(4) and 4T.743(a).)

5. The following definitions shall apply:

(a) *Clearway.* A clearway is an area beyond the runway, not less than 500 feet wide, centrally located about the extended center line of the runway, and under the control of the airport authorities. The clearway is expressed in terms of a clearway plane, extending from the end of the runway with an upward slope not exceeding 1.25 percent, above which no object nor any portion of the terrain protrudes, except that threshold lights may protrude above the plane if their height above the end of the runway is not greater than 26 inches and if they are located to each side of the runway.

NOTE: For the purpose of establishing takeoff distances and takeoff runs, in accordance with section 4T.117 of this regulation, the clearway plane is considered to be the takeoff surface.

(b) *Stopway.* A stopway is an area beyond the runway, not less in width than the width of the runway, centrally located about the extended center line of the runway, and designated by the airport authorities for use in decelerating the airplane during an aborted takeoff: To be considered as such, a stopway must be capable of supporting the airplane during an aborted takeoff without inducing structural damage to the airplane. (See also sec. 4T.115(d) of this regulation.)

SPECIAL CIVIL AIR REGULATIONS NO. SR-423

Effective: December 20, 1957
Adopted: November 15, 1957

Type Certification of Transport Category Airplanes With Turbo-Prop Replacements

The airworthiness requirements with which a particular airplane is required to comply are established by the date of application for the type certificate. After the type certificate is issued, the holder of the type certificate or an applicant for a supplemental type certificate, at his option, can obtain approval of changes in the design in accordance with requirements in effect at the time of the original application for type certificate or in accordance with later requirements in effect at the time of the change.

Prior to May 18, 1954, the regulations placed no specific limit on the extent of changes to the airplane which could be approved in this manner nor did they define a new type design for which a new application for type certification would be required. Amendment 4b-1 effective on that date, among other changes in Part 4b, lists certain changes in design which if made to an airplane would require it to be considered as a new type. In such a case, a new application for type certification would be required and the regulations, together with all amendments thereto effective on the date of the new application, would have to be complied with (sec. 4b.11(a)). One such change which would require a new type certificate is a change to engines employing different priciples of operation or propulsion (sec 4b.11(e)(2)).

Interest has been shown recently within the aviation industry in the installation of turbo-propeller engines on airplanes presently equipped with reciprocating engines. In accordance with sec. 4b.11(e)(2) such a change would require a showing of compliance with the latest airworthiness requirements of Part 4b. The Board is of the opinion that showing of compliance with all of the latest requirements might be burdensome, impractical, and not essential to safety.

This Special Civil Air Regulation will permit the certification of a turbo-propeller-powered airplane, which previously was type certificated with the same number of reciprocating engines, if compliance is shown with the airworthiness provisions applicable to the airplane as type certificated with reciprocating engines, together with certain later provisions of the Civil Air Regulations in effect on the date of application for a supplemental or new type certificate which are applicable or related to the powerplant of the turbo-propeller-powered version.

In order to insure that the level of safety of the turbine-powered airplane is equivalent to that intended by Part 4b, the Board considers that compliance must be shown with the later provisions of Part 4b which apply to the powerplant installation, airplane performance, and cockpit standardization, such other requirements as the Administrator finds are otherwise related to the changes made in the engines.

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Special Civil Air Regulation No. SR–422 establishes certain certification and operational requirements for all turbine-powered airplanes for which a type certificate is issued after the effective date of that regulation. Except as otherwise provided, all of the provisions of SR–422 remain applicable to airplanes certificated in accordance with the regulation prescribed herein. Therefore, to be certificated in accordance with the regulation prescribed herein compliance must be shown with the certification performance requirements prescribed in paragraph 2 of SR–422.

It must be emphasized that the certification performance limitations established by the performance requirements; i.e., the take-off weights, landing weights, take-off and accelerate-stop distances, and the operational limits, become part of the airworthiness certificate and must be complied with at all times, regardless of the type of operations conducted with the airplane. (See sec. 43.10, as amended, of Part 43 of the Civil Air Regulations.)

In addition to certification performance limitations, SR–422 prescribes performance operating limitations which are applicable to turbine-powered transport category airplanes when used in air carrier passenger operations. Since turbo-propeller-powered airplanes certificated in accordance with the regulation prescribed herein are required to comply with the certification performance requirements of SR–422, they are also subject to the performance operating limitations prescribed in paragraph 3 of SR–422 when used in air carrier passenger operations.

Since a change in engines will require a rather extensive change in the cockpit to accommodate the new instruments and controls for turbine engines, the Board considers that compliance with the latest cockpit standardization requirements can be accomplished without any undue burden and such compliance would speed up the cockpit standardization of other airplanes in an airline's fleet in accordance with the Board's objectives. Therefore, this regulation makes the latest cockpit standardization requirements applicable, with the exception of such detailed requirements as the Administrator finds are impracticable, and do not contribute materially to standardization. It should be noted that in referring to this exception in the preamble to Draft Release No. 56–29, the use of the conjunction "or" after the word "impracticable" was inadvertent. As the language of the proposed regulation clearly indicated, "and" was the proper conjunction following the word "impracticable."

The Board also considers it appropriate to call attention to the fact that if other changes to the airplane are made simultaneously with, or subsequent to, such an engine change, then compliance will also have to be shown with all requirements related to the additional changes in effect on the date of the new application for a supplemental or new type certificate. In this regard, if an airplane converted to turbo-propeller power is to be certificated for operation at altitudes, speeds, or weights higher than those which are applicable to the reciprocating-engine-powered airplane, compliance will be required with all the latest provisions of the regulations which are related to such changes.

In order to assure that all airplanes converted to turbo-propeller power meet the minimum requirements considered essential to safety, this regulation is made retroactive and requires compliance with the provisions of the Civil Air Regulations as set forth herein for all of such airplanes for which application for a supplemental or new type certificate was made prior to the effective date of this regulation.

This Special Civil Air Regulation shall continue in effect for 5 years, at the end of which time the effectiveness of the regulation will be evaluated for the purpose of considering the incorporation of the substance of these rules in the permanent body of the Civil Air Regulations.

Interested persons have been afforded an opportunity to participate in the making of this Special Civil Air Regulation (21 F.R. 9436), and due consideration has been given to all relevant matter presented.

In consideration of the foregoing, the Civil Aeronautics Board hereby makes and promulgates the following Special Civil Air Regulation effective December 20, 1957.

Contrary provisions of section 4b.11(a) as it applies to section 4b.11 (e)(2) of Part 4b of the Civil Air Regulations and paragraph (1) of Special Civil Air Regulation No. SR-422 notwithstanding, the following provisions shall be applicable to the certification of a turbo-propeller-powered airplane which was previously type certificated with the same number of reciprocating engines:

(1) The airworthiness regulations applicable to the airplane as type certificated with reciprocating engines and, in addition thereto or in lieu thereof as appropriate, the following provisions of the Civil Air Regulations effective on the date of application for a supplemental or new type certificate (see paragraph (3)):

(a) The certification performance requirements prescribed in Special Civil Air Regulation No. SR-422;

(b) The powerplant installation requirements of Part 4b applicable to the turbo-propeller-powered airplane;

(c) The requirements of Part 4b for the standardization of cockpit controls and instruments, except where the Administrator finds that showing of compliance with a particular detailed requirement would be impractical and would not contribute materially to standardization; and

(d) Such other requirements of Part 4b applicable to the turbo-propeller-powered airplane as the Administrator finds are related to the changes in engines and are necessary to insure a level of safety of the turbo-propeller-powered airplane equivalent to that generally intended by Part 4b.

(2) If new limitations are established with respect to weight, speed, or altitude of operation and the Administrator finds that such limitations are significantly altered from those approved for the airplane with reciprocating engines, compliance shall be shown with all of the requirements, applicable to the specific limitations being changed, which are in effect on the date of application for the new or supplemental type certificate.

(3) Airplanes converted to turbo-propeller power, for which application for a supplemental or a new type certificate was made prior to the effective date of this Special Civil Air Regulation, shall comply with all of the provisions of the Civil Air Regulations specified in paragraphs (1) and (2) effective on the date of this special regulation, rather than those provisions effective on the date application was made for the supplemental or the new type certificate.

This Special Civil Air Regulation shall terminate December 20, 1962 unless sooner superseded or rescinded by the Board.

SPECIAL CIVIL AIR REGULATION NO. SR-426

Effective: October 27, 1958
Adopted: September 22, 1958

Performance Credit for Transport Category Airplanes Equipped with Standby Power

Standby power is power and/or thrust obtained from rocket engines and is separate from the power obtained from the airplane's main engines. Such power and/or thrust is available for a relatively short period for use in cases of emergency. The standby power system may be capable of producing more than a single thrust period. This special regulation authorizes the Administrator to grant performance credit to transport category airplanes when standby power is used in one or more of the following regimes of flight: Takeoff with one engine inoperative, approach climb with one engine inoperative, and the balked landing climb. By "performance credit" is meant the taking into account the increased performance of the airplane with standby power and, because thereof, the approval of higher maximum weights for the airplane than the weights approved on the basis of the airplane's performance without standby power. In granting performance credit, this regulation prescribes the applicable conditions and limitations.

Rocket assist takeoff units were developed initially for the military services to provide additional takeoff power for heavily loaded flying boats and carrier-based aircraft. The additional thrust improved the climb performance in the takeoff regime and permitted the airplane to attain a safe altitude and air speed in the event of engine failure. The reliability of such units has increased to the point where some civil operators have adopted them for use as emergency standby power in the event of engine failure. Other operators have been reluctant to adopt standby power installations and the attendant weight penalties without reasonable performance credit being given the airplane. With the performance credit granted by this regulation for the use of standby power, it is anticipated that such credit might be considered a compensating economic factor justifying the installation of standby power on such airplanes.

The currently effective regulations did not contemplate the use of standby power; however, the Administrator of Civil Aeronautics has established for an interim period a conservative policy permitting transport category airplanes equipped with standby power to operate at an increase in the normally approved weights by an amount equal to the weight of the standby power units.

In this regulation, the criteria for granting performance credit were formulated with the intent of providing an overall level of performance equivalent to that intended by the currently effective regulations. To this end, appropriate criteria are established with respect to the amount of performance credit which may be applied in determining the new takeoff paths, the extent to which the maximum certificated takeoff and landing weights may be increased, and operating procedures to be followed in service for the use of standby power and for the associated changes in the airplane's configuration and speed.

The basic element of the various criteria established in this regulation entails a comparison of flight paths. In Civil Air Regulations

Draft Release No. 57–28, all of the flight paths were based on procedures involving attainment of the en route configuration and the acceleration to a safe en route speed. Further consideration of this proposal indicates that an undue amount of flight testing and computation would be required for those flight conditions which presently do not involve the establishment of such flight paths. In addition, it appears that comparison of flight paths involving a particular procedure is not essential for the purpose of establishing an equivalent level of safety. In view of the foregoing, this regulation requires comparison of flight paths with respect to the takeoff regime consistent only with that required by the currently effective airworthiness performance requirements; i.e., Part 4b and Special Civil Air Regulations Nos. SR–422 and SR–422A. Further, the establishment of maximum landing weights is based on a comparison of flight paths obtained with a fixed airplane configuration and at the speed and power condition appropriate to the all-engines-operating landing climb or the one-engine-inoperative approach climb, as applicable.

Performance credit for standby power with respect to the takeoff path is limited by the specification that the all-engines-operating takeoff path reflect a conservatively greater margin of overall performance than the one-engine-inoperative takeoff path with standby power in use. It is intended that this margin exist throughout the takeoff path prescribed by the applicable performance requirements. This regulation provides for the establishment of the margin by the Administrator; however, in no case can this margin be less than 15 percent. In view of the many different types of airplanes to which this regulation is applicable, a higher margin might be necessary in certain cases to insure safe day-to-day operations.

For reciprocating-engine-powered airplanes, the provisions of this regulation require that the applicant establish a procedure for the use of standby power for attaining the en route configuration and a safe en route speed in the event of an engine failure during the takeoff. Provisions for such procedures are contained in the regulations for turbine-powered airplanes and will therefore be applicable to such airplanes. The establishment of the procedures made applicable to reciprocating-engine-powered airplanes is left to the discretion of the applicant to select the altitude at which the acceleration is to take place, the basic limitation being that the slope along all points of the airborne portion of the takeoff path must be positive. This will provide for the critical operation of cleanup and acceleration during the takeoff which are not covered by the performance requirements of Part 4b and which have been cited in the past in connection with several accidents. In addition, with respect to the clearing of obstacles, the takeoff path scheduled in the Airplane Flight Manual for airplanes for which the performance requirements of Part 4b are applicable must be appropriately modified to reflect the effect of the aforementioned procedure.

The criteria for the establishment of maximum certificated takeoff weights involve two separate comparisons of takeoff paths. These comparisons must be carried out to a height of 400 feet above the takeoff surface. This minimum height is intended to be associated with a procedure where standby power is actuated within the neighborhood of the critical engine failure speed V_1. These provisions are intended to limit the increase in maximum takeoff weight consistent with the overall level of performance currently attained with respect to the one-engine-inoperative takeoff and to limit the amount of standby power for which performance credit can be granted to insure a reasonable margin of performance for the all-engine day-to-day operations.

The provisions for the establishment of maximum certificated landing weights require only a comparison between two flight paths based on a steady climb and fixed configuration. One represents a climb path at the maximum weight previously certificated without standby power and the other a climb path at the increased weight with standby power. In addition, there is a provision which requires the establishment of procedures for the execution of balked landings and missed approaches in conjunction with the use of standby power.

A question has been raised as to whether duplicate sets of standby power units are required to obtain performance credit for both the takeoff and the approach stages of flight. It is intended by this regulation to require duplicate sets of standby power for a flight for which the use of standby power is necessary to comply with both the maximum certificated takeoff and the maximum certificated approach weight limitations. Where the use of standby power is necessary for compliance with the maximum certificated weight limitations for only one regime of flight, i.e., takeoff or approach, one set of standby power units is required.

There are also included safety criteria for the installation and operation of the standby power system.

The Board presently has under consideration a special regulation which would be applicable to nontransport category airplanes equipped with standby power.

Interested persons have been afforded an opportunity to participate in the making of this regulation (22 F.R. 10464), and due consideration has been given to all relevant matter presented.

In consideration of the foregoing, the Civil Aeronautics Board hereby makes and promulgates the following Special Civil Air Regulation, effective October 27, 1958.

Contrary performance provisions of the Civil Air Regulations notwithstanding, the Administrator may grant performance credit for the use of standby power on transport category airplanes. Such credit shall be applicable only to the maximum certificated takeoff and landing weights, the takeoff distance, and the takeoff paths, and shall not exceed that found by the Administrator to result in an overall level of safety in the takeoff, approach, and landing regimes of flight equivalent to that prescribed in the regulations under which the airplane was originally certificated without standby power. (Note: Standby power is power and/or thrust obtained from rocket engines for a relatively short period and actuated only in cases of emergency.) The following provisions shall apply:

(1) *Takeoff; general.* The takeoff data prescribed in sections (2) and (3) shall be determined at all weights and altitudes, and at ambient temperatures if applicable, at which performance credit is to be applied.

(2) *Takeoff path.*

(a) The one-engine-inoperative takeoff path with standby power in use shall be determined in accordance with the performance requirements of the applicable airworthiness regulations.

(b) The one-engine-inoperative takeoff path (excluding that portion where the airplane is on or just above the takeoff surface) determined in accordance with paragraph (a) of this section shall lie above the one-engine-inoperative takeoff path without standby power at the maximum takeoff weight at which all of the applicable airworthiness requirements are met. For the purpose of this comparison, the flight path shall be considered to extend to at least a height of 400 feet above the takeoff surface.

(c) The takeoff path with all engines operating, but without the use of standby power, shall reflect a conservatively greater overall level of performance than the one-engine-inoperative takeoff path established in accordance with paragraph (a) of this section. The aforementioned margin shall be established by the Administrator to insure safe day-to-day operations, but in no case shall it be less than 15 percent. The all-engines-operating takeoff path shall be determined by a procedure consistent with that established in complying with paragraph (a) of this section.

(d) For reciprocating-engine-powered airplanes, the takeoff path to be scheduled in the Airplane Flight Manual shall represent the one-engine-inoperative takeoff path determined in accordance with paragraph (a) of this section and modified to reflect the procedure (see sec. (6)) established by the applicant for flap retraction and attainment of the en route speed. The scheduled takeoff path shall have a positive slope at all points of the airborne portion and at no point shall it lie above the takeoff path specified in paragraph (a) of this section.

(3) *Takeoff distance.* The takeoff distance shall be the horizontal distance along the one-engine-inoperative takeoff path determined in accordance with section (2)(a) from the start of the takeoff to the point where the airplane attains a height of 50 feet above the takeoff surface for reciprocating-engine-powered airplanes and a height of 35 feet above the takeoff surface for turbine-powered airplanes.

(4) *Maximum certificated takeoff weights.* The maximum certificated takeoff weights shall be determined at all altitudes, and at ambient temperatures if applicable, at which performance credit is to be applied and shall not exceed the weights established in compliance with paragraphs (a) and (b) of this section.

(a) The conditions of section (2) (b) through (d) shall be met at the maximum certificated takeoff weight.

(b) Without the use of standby power, the airplane shall meet all of the en route requirements of the applicable airworthiness regulations under which the airplane was originally certificated. In addition, turbine-powered airplanes without the use of standby power shall meet the final takeoff climb requirements prescribed in the applicable airworthiness regulations.

(5) *Maximum certificated landing weights.*

(a) The maximum certificated landing weights (one-engine-inoperative approach and all-engines-operating landing climb) shall be determined at all altitudes, and at ambient temperatures if applicable, at which performance credit is to be applied and shall not exceed that established in compliance with the provisions of paragraph (b) of this section.

(b) The flight path, with the engines operating at the power and/or thrust appropriate to the airplane configuration and with standby power in use, shall lie above the flight path without standby power in use at the maximum weight at which all of the applicable airworthiness requirements are met. In addition, the flight paths shall comply with the provisions of subparagraphs (i) and (ii) of this paragraph.

(i) The flight paths shall be established without changing the appropriate airplane configuration.

(ii) The flight paths shall be carried out for a minimum height of 400 feet above the point where standby power is actuated.

(6) *Airplane configuration, speed, and power and/or thrust; general.* Any change in the airplane's configuration, speed, and power and/or thrust shall be made in accordance with the procedures established by the applicant for the operation of the airplane in service and shall comply with the provisions of paragraphs (a) through (c) of this section. In addition, procedures shall be established for the execution of balked landings and missed approaches.

(a) The Administrator shall find that the procedure can be consistently executed in service by crews of average skill.

(b) The procedure shall not involve methods or the use of devices which have not been proven to be safe and reliable.

(c) Allowances shall be made for such time delays in the execution of the procedures as may be reasonably expected to occur during service.

(7) *Installation and operation; standby power.* The standby power unit and its installation shall comply with the provisions of paragraphs (a) and (b) of this section.

(a) The standby power unit and its installation shall not adversely affect the safety of the airplane.

(b) The operation of the standby power unit and its control shall have proven to be safe and reliable.

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U. S. CIVIL AERONAUTICS AUTHORITY

M A N U A L

14 AIRCRAFT PROPELLER AIRWORTHINESS

December 1, 1938

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MANUAL

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INTRODUCTORY NOTE

This manual is supplementary to the Civil Air Regulations, Part 14, referred to herein by the Code of Federal Regulations designation 6 CFR 14. The material contained herein is intended to explain and interpret the various requirements of 6 CFR 14, to expedite the presentation of the desired technical data, and to outline what is considered acceptable practice in certain instances.

It should be understood that any method which can be shown to be the equivalent of one set forth in this manual will be equally acceptable to the Authority. Likewise, any interpretation herein shown to be inapplicable to a particular case will be suitably modified for such case on request. In either event such acceptance or modified interpretation will be effective as and when issued prior to subsequent incorporation herein. This manual will be revised from time to time as equally acceptable methods, new interpretations, or the need for additional explanation are brought to the attention of the Authority.

The material in this manual is arranged for direct correspondence with the requirements. For example, CAAM 14.1-A3 refers to a specific breakdown of 6 CFR 14.1. On the reverse side of this page will be found a form for convenience in maintaining a record of subsequent revisions.

CIVIL AERONAUTICS AUTHORITY MANUAL

14 AIRCRAFT PROPELLER AIRWORTHINESS

.0 GENERAL

.00 PROVISION FOR RATING

1. It should be noted that 6 CFR 14 concerns the rating of propellers for use on engines specifically, and on aircraft only insofar as the complete powerplant unit is eventually installed and operated on an airplane. An operation limit specified in accordance with this chapter approves the propeller for use with a certain engine or type of engine. The pertinent requirements of 6 CFR 04, regarding the functioning of the installed powerplant unit and the performance of the complete airplane, are, of course, applicable whenever a new propeller design is installed. If the propeller model or type is listed on the pertinent airplane specification it has met these latter requirements.

.012 PRODUCTION CERTIFICATE

A 1. GENERAL. Recommended practices requisite for the production of wood and metal propellers under a production certificate are discussed separately below. (See also 6 CFR 01.521). In either case it should be noted that a semi-annual report of the production is required in January and July of each year in accordance with 6 CFR 01.76.

B WOOD PROPELLERS.

1. Due to the stabilized nature of fixed-pitch wood propeller construction the procedure and equipment have evolved to the point where certain minimum standards may be set forth. The following items are intended to present such standards in materials, processes, manufacturing tolerances, and inspection methods.

2. The materials of construction should be of the highest quality obtainable because of the highly stressed condition of a propeller and its relative importance as a primary powerplant item. The following details should be noted:

a. Wood used should be purchased from a reputable lumber company under a detailed specification as to its characteristics. It is recommended that all lumber from which propeller laminae are to be cut be kiln dried to a moisture content of between seven and ten percent. The minimum specific gravity of the various woods (based on oven dry weight and volume) should be as follows:

Birch, sweet or yellow	0.58
Oak, white	0.65
Walnut, black	0.52
Mahogany, African	0.48

Spiral or diagonal grain should have a slope of less than 1 in 10 when measured from the longitudinal axis of the laminae. The wood should be free from checks, shakes, rot, and excessive worm holes. To reduce the effect of internal variations present in all wood, the importance of selecting a high grade of material cannot be over emphasized.

b. Glue used should be of a high quality animal or casein type. Blood albumin glues, marine glues, and the various phenol-aldehyde adhesives are not considered satisfactory due either to their peculiar properties or method of application.

c. Varnish used should be a high quality spar varnish or its equivalent. In any event, the coating used must be transparent to facilitate field inspection for cracks and opened glue joints.

d. Tipping materials should be of a good grade brass, monel metal, stainless steel, or the equivalent. The recommended minimum thickness is 0.022 inches. A linen fabric is frequently applied to the surface for additional strengthening at the tip and for protection against abrasion and splintering. It should be finished with transparent dope or varnish but metal tipping need not be.

3. Processes and methods employed in the fabrication of the propeller shall be those definitely known to yield the best construction. The following sequence of operations and methods employed is presented because, if carefully followed, it will result in an airworthy product.

a. Laminations should be laid out with the longitudinal axis parallel to the grain of the boards from which they are to be cut. All lumber should stand under shop conditions at least 24 hours to thoroughly adjust itself before working. It has been found satisfactory to either blank out the laminations prior to glueing or to glue up a rectangular block and rough it down to shape. Hub wideners may be incorporated in all but the outer laminae if so shown on the sealed drawing. The widener joint must clear the outer edge of the hub bolt holes by at least one bolt hole diameter and adjacent joints must be staggered. Spliced laminae will not be permitted in general although certain instances may be allowed on the basis of overspeed whirl tests. Such cases will be considered individually. Laminae thickness may vary from 1/2" to 1" but any further variation should be shown on the sealed drawings. Laminae of the same thickness should be used in a propeller, except for outside ones. After passing inspection the laminae should be planed to thickness on a suitable planer or joiner. Prior to assembly for glueing the laminae should be separated into three classes: light, medium and heavy. Only laminae of one class should be assembled in a single propeller. These should be individually balanced and assembled with the heavy ends of adjacent laminae at opposite ends to facilitate balancing.

b. Glue. Due care should be used in mixing and applying the glue. Casein glue should never be mixed at a speed greater than 120 rpm and the majority of the mixing should be done at half this speed. The complete mixing operation should be accomplished in 20 to 30 minutes. Too rapid stirring beats an excessive amount of air into the mixture, which tends to weaken the glued joint. If lumps are present at the completion of the mixing the batch should be discarded. A dough-type of mixer with a two-speed electric motor is considered preferable. The glue-water proportions for animal glue should be as specified by the manufacturer. The proper spread of glue is about 7 3/4 lbs per 100 square feet of surface when applied to only one face of the joint. With Casein glue a pressure of 150 to 200 p.s.i. should be applied. Slight variations from ordinary room temperatures do not require any important change in assembly time. However, with animal glue there is a definite relationship between temperature and assembly time. For a detailed discussion of this point refer to Trayer, "Wood in Aircraft Construction", pages 103--115. Figure 1 has been made up from this source.

OPTIMUM GLUEING CONDITIONS USING ANIMAL GLUE

Species	Glue-Water proportions by weight.	Approximate Glue Spread	Temperature of Wood	Pressure	Assembly Time (*)
	1:2 1/4	7 3/4 lbs per	70°F	150-200p.s.i.	1/2-1 min.
Mahogany	1:2 1/4	7 3/4 100 sq ft.	80	150-200	2-5
	1:2 1/4	7 3/4	90	150-200	7-18
Yellow Birch	1:2 1/4	7 3/4	70	200	1
White Oak	1:2 1/4	7 3/4	80	200	3-5
Black Walnut	1:2 1/4	7 3/4	90	200	12-18
White Ash	1:2	7 3/4	70	200	1/2

* Assembly time based on wood pieces being laid together as soon as spread with glue.

FIG. 1

c. Pressing may be accomplished manually by the use of C-clamps or by a jack-press. In any event, the pressure range defined in the preceding paragraph should not be exceeded. The pressing time for both casein and animal glues should be at least five hours, with a greater time desirable. A conditioning period of at least seven days should be allowed after removal from the press or clamps.

d. Shaping. After conditioning, the propeller should be roughed out to within 1/8 inch of the finished surface, either by hand or with a profiling machine. After this operation the propeller should be conditioned for an additional seven days or more at approximately 70°F. and 40% relative humidity.

e. Finishing. The propellers should be carved and worked to a final size using suitable templates and a bubble protractor. Final operations should include a smooth sanding. The propeller should be rigidly mounted for these operations. The change in pitch angle from station to station shall be smooth and true throughout the blade length with no irregularities in contour. A set of metal templates suitably stamped should be available for this stage.

f. Drilling. The hub holes should be drilled with extreme accuracy, using a suitable jig and taking care to insure that the holes are perpendicular to the hub faces.

g. Tipping. The tipping material should be attached to the leading edge with No. 4 wood screws, 1/2 inch or 3/8 inch long out to 1/2 inch blade thickness. Outboard of this point 3/32 inch diameter brass or copper rivets should be used. The blade should be drilled and countersunk for the screws. The rivet holes should be drilled after the tipping is screwed on. The metal tipping should not be countersunk either for the screws or rivets. The rivet heads and screw heads should be filled with solder and filed down to a smooth surface. The metal tipping should be vented by drilling several holes in the tip after assembly. (Three 0.040 in. diameter holes to a depth of 1/2 in. are recommended.)

h. Finish. One coat of varnish should be applied prior to, and at least two coats after, tipping. A priming coat of valoil or a paste wood filler may be applied initially. The hub bore should also receive several coats of varnish. In any event the finish coat must be transparent throughout to allow inspection for cracks and opened glue joints.

i. Horizontal Balance. The propeller should be balanced after shaping and after each successive operation that might affect the balance. Final balance should be accomplished on a rigid knife-edge balancing stand in a room free from air currents. No persistent tendency to rotate from any position on the balance stand should be present.

Horizontal unbalance may be corrected by the application of clear varnish or solder to the light blade. The light blade may be coated with a high grade of clear primer allowing for a finishing coat of clear varnish. After allowing each coat to dry 48 hours, the balance should be checked. Then, as may be necessary, either the required amount of varnish should be removed by carefully sandpapering or an additional coat applied, allowing for the finishing coat of varnish which should be a thin coat of high grade clear spar varnish. The balance should be rechecked and sandpaper or additional varnish applied as may be required to effect final balancing. Only clear finish is permitted.

j. Vertical unbalance may be corrected by applying putty to the light side of the wood hub at a point on the circumference approximately 90 degrees from the longitudinal centerline of the blades. The putty should be weighed and a brass plate weighing slightly more than the putty should be cut out. The thickness of the plate will be from 1/16 to 1/8 inch depending on the final area, which must be sufficient for the required number of flat head attaching screws. The plate should be formed to fit the shape of the light side of the wood hub, and drilled and countersunk for the required number of screws. The plate should then be attached and all of the screws tightened. After the plate is finally attached to the propeller, the screws should be secured to the plate by soldering the screw heads. The balance should be checked and all edges of the plate beveled to reduce its weight. The drilling of holes in the propeller and the insertion of lead or other material to assist in balancing will not be permitted.

4. Inspection. An inspection system should be established to accomplish adequate checks on material being used, tolerances on the finished product, and balance. Recommended tolerances and forms are discussed below in Figure 2 and items (a), (b), and (c).

WOOD PROPELLER TOLERANCES

Blade length		± 1/16"
Blade width	(shank to 24 inch station))	± 3/32"
	(24 inch station to tip)	± 1/16"
Blade thickness	(shank to 24 inch station)	+ 1/8", -1/16"
	(24 inch station to tip)	+ 3/64"
Edge alignment		+ 1/16"
Face alignment		± 1/8"
Template fit	(shank to 24 inch station)	3/32"
	(24 inch station to tip)	1/32"
Blade angle	(shank to 18 inch station)	± 1.0°
	(24 inch to 30 inch station)	± 0.5°
	(36 inch station to tip)	± 0.4°
Track		1/16"
Thickness of hub		± 1/32"
Diameter of hub		± 3/32"
Hub bolt holes		+ .005"

FIG. 2

a. By edge alignment is meant the distances parallel to the respective chords of the sections from the center line of the blade to the leading edges of the cross-sections of the blade at the various stations. By face alignment is meant the distances from the center line of the blade to its thrust or working face as measured perpendicular to the chords of the blade at the various stations.

b. Blade thickness may be checked with a pair of calipers. The hub bolt holes should be checked with an exact size "go" gage and a 0.010 inch oversize "no-go" gage.

c. A suitable final inspection form should be completed and filed for every propeller produced. Figure 17 on page 39 is a suggested form for this purpose. This form should be signed by some responsible person designated as Chief Inspector by the company. On the back of the form the production tolerances (see Figure 2) should be printed.

C METAL PROPELLERS

1. Because the art of producing an airworthy metal propeller of the various types is highly individualistic and because such production may properly be accomplished on a variety of machinery and equipment, this section will be confined to indicating what is acceptable in the way of manufacturing tolerances and balancing and inspection methods. Forged solid aluminum alloy blades, forged solid steel blades or welded hollow-steel blades retained in a forged steel hub construction have proven acceptable types of construction thus far and will be discussed in order. The workmanship and material of all types should be of a high quality. All blades and hubs should be finished smooth and free from defects, visible scratches, and tool marks. The effect of surface roughness in creating high local stress concentrations and promoting fatigue failure is such as to easily be critical in any design.

2. Forged solid aluminum alloy blades or one piece propellers may be forged solid or machined from a forged billet. Great care should be exercised in securing a high quality of material and a sound forging. It is recommended that a check be made in the physical and chemical properties of each forging or billet used by extracting a test piece and subjecting it to a complete physical and chemical test.

a. For inspection purposes each blade should be etched in a 20% caustic soda solution and cleaned in a 20% nitric acid solution and warm water. The blades should be carefully examined with a three power magnifying glass for the presence of cracks and other defects. Suspected defects should be repeatedly etched until their nature is determined. A crack will appear as a distinct black line. Transverse cracks of any size or description are sufficient cause for rejection provided they cannot be worked out within the tolerance limits as given in 14.012-C2(b) herein. Longitudinal cracks which increase in size as the surface metal is removed are also considered cause for rejection provided they cannot be worked out within the above-mentioned tolerance. Small longitudingal inclusions, if relatively few in number, may be passed at the inspector's discretion. Blades which show excessive amounts of inclusions, scabbiness, or other abnormal conditions which cannot be worked out within the tolerance limits, must be rejected.

b. Blades of the same design should be interchangeable in all respects. This requirement dictates to a large extent the necessary production tolerances and balancing requirements. The recommended production tolerances for forged aluminum alloy blades are given below in Figures 3 and 4.

ALUMINUM ALLOY BLADE PRODUCTION TOLERANCES

Basic Diameter -- 10 ft. 6 in., or less		
Blade length		± 1/16"
Blade width	(shank to 24 inch station)	± 3/64"
	(30 inch station to tip)	± 1/32"
Blade thickness		± .025"
Edge alignment		± 1/32"
Face alignment		± 1/32"
Template fit	(shank to 24 inch station)	1/32"
	(30 inch station to tip)	.020"
Blade angle	(shank to 18 inch station)	± 0.5°
	(24 inch to 30 inch station)	± 0.25°
	(36 inch station to tip)	± 0.20°
Longitudinal location of stations		± 0.015"

FIG. 3

ALUMINUM ALLOY BLADE PRODUCTION TOLERANCES

Basic Diameter -- over 10 ft. 6 in.		
Blade length		± 1/16"
Blade width	(shank to 24 inch station)	± 1/16"
	(30 inch station to tip)	± 1/32"
Blade thickness	(shank to 24 inch station)	± 0.030"
	(30 inch station to tip)	± 0.025"
Edge alignment	(shank to 24 inch station)	± 1/16"
	(30 inch station to tip)	± 1/32"
Face alignment	(shank to 24 inch station)	± 1/16"
	(30 inch station to tip)	± 1/32"
Template fit	(shank to 24 inch station)	3/64"
	(30 inch station to tip)	0.020"
Blade angle	(shank to 24 inch station)	± 0.5°
	(30 inch station to tip)	± 0.25°
Longitudinal location of stations		± 0.015"

FIG. 4

Edge and face alignment are defined in 14.012-B 4(a) herein.

c. The interchangeability requirement of the proceding paragraph requires that all blades of the same design balance against each other throughout the entire range of blade angles. This may be accomplished by checking each blade against a master blade or a master cylinder. It is recommended that the balancing equipment for this operation be within a sensitivity of 0.04 inch-pounds in horizontal balance and 0.2 inch-pounds in vertical balance. The finished propeller should balance both horizontally and vertically at both 0 and 90 degrees to the plane of rotation without showing a persistent tendency to rotate in any direction. Final balancing should be done on a knife-edge balancing stand in an enclosed room which is free from air currents. Horizontal balance may be corrected by drilling a concentric hole in the base of the blade which hole must conform with the specifications of Figure 5. Vertical balance may be corrected by drilling an eccentric hole not greater than 3/8 inch in diameter to a depth not exceeding that specified in Figure 5. The outer edge of this hole shall not be closer than 1/4 inch to the nearest external blade surface and not more than one eccentric hole should be drilled per blade. These holes may be left open or filled with lead. Leaded holes should be corked.

SIZE AND DEPTH OF BALANCING HOLES

Shank Size	Maximum concentric hole diameter	Maximum concentric hole depth	Maximum eccentric hole depth. (3/8 in. max. dia.)
00	7/16 inches	2 1/2 inches	2 1/4 inches
0-1/2	19/32	3 3/8	3
1/2	5/8	3 5/8	3 1/2
1	3/4	4 1/4	4
1 1/2	13/16	4 7/8	4 1/2
2	7/8	5 1/2	5
3	31/32	6 1/8	6

FIG. 5

As an alternative to drilling the two holes mentioned above, a single eccentric hole having a diameter and depth conforming to the concentric hole dimension given in Fig. 5 may be drilled and filled with lead. The outer edge of this hole should not be closer than one inch to the nearest external blade surface. The ends of all balancing holes should be finished with a full size drill having a spherical end to eliminate corners. The sharp edges of the hole should be removed by a 1/32 inch chamfer. Blades having special hub ends which are designed for use in controllable pitch propellers should not be drilled with this eccentric balancing hole.

3. Forged solid steel blades may be forged solid or machined from a forged or rolled billet of suitable alloy steel. A check should be made of the physical properties by taking a test specimen from each and subjecting it to complete physical tests after heattreating. An ample check should also be made of the chemical content of the material.

a. All blades should be inspected by the wet magnaflux process for discontinuities, cracks, and other defects. Any unsatisfactory indications which cannot be worked out within the tolerance limit below should be sufficient cause for rejection. The magnaflux inspection should be under the direct supervision of highly-experienced personnel.

b. Acceptable production tolerances for solid steel blades are given in Figure 6.

SOLID STEEL BLADE PRODUCTION TOLERANCES

Blade length		± 1/16"
Blade width	(from shank to 24 in.station)	± 1/16"
	(from 24 in. station to tip)	± 1/32"
Blade thickness	(from shank to 24 in.station)	± 0.030"
	(from 24 in. station to tip)	± 0.025"
Edge alignment	(from shank to 24 in.station)	± 1/16"
	(from 24 in. station to tip)	± 1/32"
Face alignment	(from shank to 24 in.station)	± 1/16"
	(from 24 in. station to tip)	± 1/32"
Template fit	(from shank to 24 in.station)	3/64
	(from 24 in. station to tip)	0.020"
Blade angle	(from shank to 24 in.station)	± 0.50°
	(from 24 in. station to tip)	± 0.25°
Longitudinal location of stations		± 0.015"

FIG. 6

Edge and face alignment are defined in 14.012-B 4(a) herein.

c. Blades of the same design should be interchangeable in all respects. They should, therefore, balance against each other throughout the operating range of blade angles. This may be accomplished by checking each blade against a master blade or cylinder. The balancing apparatus should have a sensitivity of approximately 0.04 inch-pounds in horizontal balance and 0.2 inch-pounds in vertical balance and should be used in a room free from air currents. The blades should balance both horizontally and vertically when set at both 0 and 90 degrees to the plane of rotation. Inserts or balancing plugs used in the blade shanks for the correction of unbalanced conditions will be considered individually. In all cases they should be shown on the sealed drawing.

4. Welded hollow-steel blades should be welded up from suitable sheets or strips of steel alloy. The material used in this type blade should be heat-treated to obtain the following minimum physical properties:

Ultimate tensile strength	125,000 p.s.i.
Proportional limit	65,000 p.s.i.
Elongation	12%

Blades of this type should be made from blanking dies, forming dies, welding jigs, heat-treat jigs and similar production tools with a minimum of filing, grinding, wedging, or other hand operations. A standard tension test sample should be cut from each sheet of steel used and subjected to physical tests to determine the above properties. Sufficient chemical analyses should also be run to determine the chemical properties of the material and to assure a uniform composition.

a. All blades should be inspected at various times during the production process by means of the wet magnaflux process. A frequent number of inspections will be found desirable in order to eliminate a large number of rejections in the final stage of production. Any pronounced magnaflux indications which cannot be eliminated by removing a maximum of 10% of the plate thickness at this stage are considered sufficient cause for rejection. The magnaflux inspections should be under the direct supervision of highly-experienced personnel. Adequate visual inspection should also be accomplished to detect incomplete welds, concentration of welding material, and the abrupt termination of a weld in such a manner as to constitute a stress concentration point.

b. Recommended production tolerances for hollow-steel blades are given in Figure 7.

HOLLOW STEEL BLADE PRODUCTION TOLERANCES

Blade length		± 1/16"
Blade width	(from shank to 24 inch station)	± 1/16"
	(from 24 inch station to tip)	± 3/64"
Blade thickness	(Maximum ordinate)	± 0.045"
Edge alignment		± 1/8"
Face alignment		± 0.045"
Template fit	(from shank to 24 inch station)	1/16"
	(from 24 inch station to tip)	0.045"
Blade angle	(from shank to 24 inch station)	± 1.0°
	(from 24 inch station to tip)	± 0.5°
Longitudinal location of stations		± 1/16"

FIG. 7

Plate thickness should be held to the following limits:

0.375 to 0.565 thickness	-0.004, +0.015
0.156 to 0.375 thickness	-0.003, +0.010
0.060 tp 0.156 thickness	-0.002, +0.005

Edge and face alignment are defined in 14.012-B 4(a) herein. The surfaces and edges between stations should be of fair contour.

5. Forged steel hubs should be forged in a die from medium carbon, chrome-vanadium, or chrome-nickel-steel bars or the equivalent. Chrome-vanadium steel hubs should have a Brinell hardness of 295 ± 20 (10 mm. ball, 3000kg) in the center of the thickest portion. Chrome-nickel steel hubs should correspondingly have a Brinell hardness of 305 ± 20. Either material should show at least the following minimum physical properties:

Ultimate tensile strength	135,000 p.s.i.
Yield strength	115,000 p.s.i.
Elongation	15%
Reduction in area	50%

Suitable test specimens should be taken from each hub forging to check these physical properties. Sufficient chemical analyses should also be run to determine the chemical properties of the material and to assure a uniform composition. One or more forgings from each new die should be examined for the proper grain flow.

a. All hubs should be inspected by means of the wet magnaflux process. Any pronounced magnaflux indications which cannot be eliminated within the tolerance limit of the design are considered sufficient cause for rejection of the part. The magnaflux inspection should be made under the direct supervision of highly-experienced personnel.

b. There are no general recommended production tolerances for forged steel hubs. Under 14.1-C 5(b) herein are given the recommended dimensions and tolerances for detachable-blade non-controllable propeller hubs. Recommended dimensions and tolerances for that portion of the controllable hub which mates with the engine shaft are given in 14.1-C 5(d) herein.

c. The correctly balanced hub should stand at any angle in the balancing apparatus without displaying a persistent tendency to move in any direction. In order to obtain final balance of the hub, metal may be removed from the portions of the hub where a surplus has been left for balancing purposes, such as shown in Figure 8. The tolerance limit must however not be exceeded in any case.

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HUB MATERIAL REMOVABLE FOR BALANCING

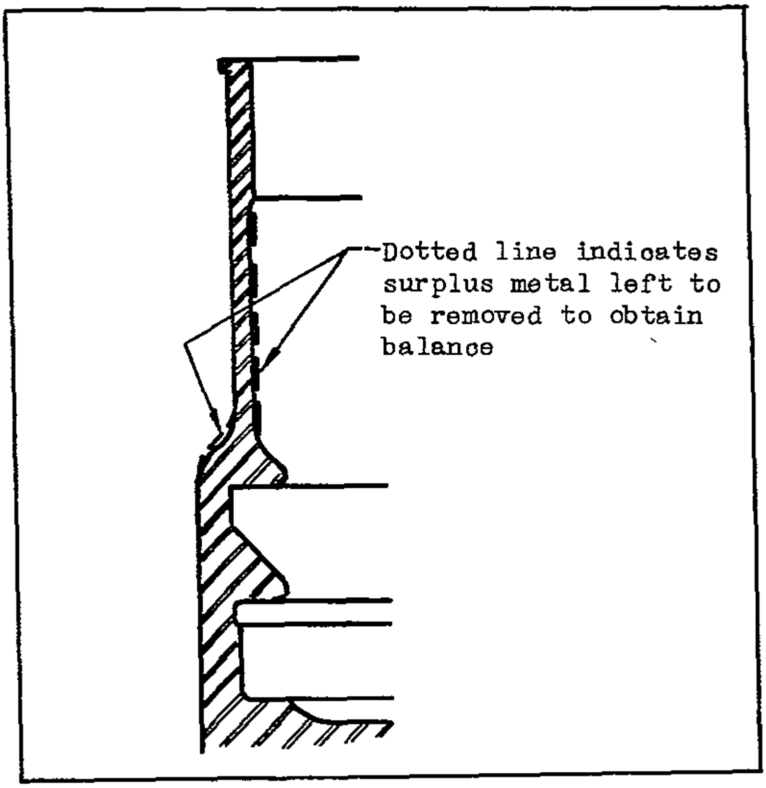

FIG. 8

d. Hub holes, threads and splines should be checked with suitable "go" and "no-go" gages made up on the basis of the allowable manufacturing tolerances.

.013 DEVIATIONS

1. The term unconventional, as used in 6 CFR 14.013, refers to deviations from the conventional with respect to general design and design details. Materials and types of construction other than those mentioned herein are considered unconventional and applications should accordingly be made to the Authority for special rulings covering the design. If there exists any doubt in the mind of the designer as to whether his design is conventional or not, the entire design should be discussed prior to making active preparations for a test program.

.02 HUBS AND BLADES

1. When propeller hubs and blades are interchangeable they are certificated as separate units and this procedure requires the submittal of a complete set of data both for the propeller blade and hub as these data are filed separately.

.03 TESTING FACILITIES

1. It is necessary that the manufacturer conduct all propeller tests and supply or arrange for the proper testing facilities. This normally requires the following equipment:

a. A new engine (or one in good repair) of the type for which certification of the propeller is desired. If it has not been overhauled recently a top inspection or overhaul may be warranted.

b. A suitable engine mount.

c. An accurate tachometer, which should be calibrated before and after testing and checked with a stop watch and revolution-counter during testing.

d. A suitable manifold pressure gage if the test is not run at full throttle. (Not required for fixed-pitch wood propeller tests)

e. Sufficient vibration equipment to ascertain beyond reasonable doubt that the propeller will not encounter dangerous resonance conditions in operation. (Necessary only in the case of metal propellers.) Such equipment should preferably consist of a suitable gigolo to conduct static vibration tests; and suitable vibration stress pick-ups and recorders*, the former to be mounted on the blades and used to record the vibration stresses during operation; a suitable torsiograph to determine the torsional characteristics of the propeller-crankshaft system; and suitable linear pick-ups to determine the motion of the engine in space.

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* Thus far one of the most effective pieces of apparatus has been found to be carbon-strip strain gages connected through slip-rings to a 12 volt D.C. source with a resistor, condenser, amplifier and oscillograph in the hook-up. For additional information on this type of apparatus refer to the Journal of the Aeronautical Sciences, Vol. 5, No. 2, pp. 37-52: "Propellers for Aircraft Engines of High Power Output" by F. W. Caldwell.

.05 PROPELLER OPERATION LIMITS

1. Upon completion of the necessary testing the propeller is certificated for a specified horsepower, rpm, and engine bore limit with a certain diameter and pitch range. Due to the difference in vibration characteristics with different crankshaft systems and gear ratios it has recently been found necessary to supplement these general factors with a qualifying statement as to the specific engine or series of engines for which operation is certificated. Unless definitely stated to the contrary the propeller is assigned a take-off (one minute) operation limit of 10% in excess of the maximum, except take-off limit in power and in speed. Fixed-pitch wood propellers are normally certificated only for a horsepower and rpm with no further qualifications other than diameter and pitch. Due to the type of testing employed (see 14.22 herein) the horsepower is often an approximation with the result that the propeller is essentially certificated for operation not in excess of a given rpm.

.06 PROPELLER IDENTIFICATION DATA

1. In addition to the data specified in 6 CFR 14.06 some manufacturers have found it desirable to stamp the approval number on the propeller. This has the advantage of giving the inspector or owner a basic reference to the current specification for the operation limits applicable. It is suggested that this item be added but it may not be substituted for the other required data.

.1 DESIGN REQUIREMENTS

A GENERAL

1. Design requirements and recommendations will be discussed separately for wood and metal propellers. 6 CFR 14.10, 14.11, 14.12, and 14.13 are covered in this general discussion.

B WOOD PROPELLERS

1. The matter of recommended finishes, materials, tolerances, hub wideners and balancing has previously been discussed for this type of propeller under 14.012-B herein. Problems of a design nature will be considered under this topic as quantitatively as possible.

2. Blades should be laid out with a faired contour in planform and thickness. Abrupt changes in cross-section are to be avoided.

Curves of maximum thickness and of minor and major moments of inertia versus radius should be developed and submitted to check this point on new designs. The center of gravity of the blade sections is preferably a straight line or nearly so in the planform view. This line should have a slight forward tilt to relieve the aerodynamic load on the blade. The condition of take-off and climb probably subjects this type of propeller to the most severe steady loads due to the small relieving action of the centrifugal force at the low revolution speeds combined with the high thrust loadings.

3. Blade tip sections should be designed with great care. In general, thin tip sections have caused trouble even in wood propellers and are to be avoided. The designer might well use a slightly thicker tip section at the expense of some propulsive efficiency. Markedly thin tips with their accompanying flexibility tend to promote flutter and resonance conditions. It does not follow that a thick tip insures against flutter and resonance, however, a thick tip on a well-designed blade is preferable structurally if not aerodynamically.

4. Some trouble has been experienced with blade tipping due to poor location of the attaching screws and rivets. These attachments should not be in a straight line parallel to the grain of the wood as this promotes cracking along sections in line with the screws.

5. The finish of the wood propeller should be transparent as required in 6 CFR 14.13 and discussed in 14.012-B3 (h) herein. This is to facilitate inspection for cracks and opened glue joints at the time of the annual inspection.

6. To promote a standardization of propeller hub attachments it is recommended that steel hubs for wood propellers be designed in conjunction with the engine shaft according to the SAE standard dimensions. As this type of hub is ordinarily designed, manufactured and certificated as an engine part, it is only mentioned here in passing. The front flange should preferably be splined to the hub proper in all except designs for 50 hp. or less. This matter and other pertinent design data will be discussed under boss design in 14.1-B 7 herein.

7. The extensive service use of the fixed pitch wood propeller has made it possible to investigate portions for quantitative design criteria. The following analysis of this type propeller has been made from the viewpoint of experience.

a. The boss (or hub portion) is stressed chiefly by the steady air loads and centrifugal loads with the engine torque impulses superimposed. The torque impulses prove the most severe for the boss, and service failures give a definite indication of this in burned and elongated bolt holes. Once these holes are elongated and the propeller starts to rock on its hub the bolts are subjected to abrupt eccentric loads which tend to shear the bolt heads.

b. For the majority of designs the rear flange of the steel hub is integral with the splined portion which mates with the crankshaft, while the front flange may be splined to the hub or simply serve as a collar. Assuming the engine torque to be resisted only by the bearing area of the hub bolts and neglecting the effect of friction between the wood and metal surfaces*, it is possible to calculate the "propeller resisting torque" for a specific design. This must be modified for some designs to account for the added strength of splining the front flange. If the hub bolts were rigidly supported at each end their bearing strength would increase 100% over the cantilever type. Because of the varying amounts of play in the splined front flange this 100% increase has been arbitrarily reduced to 25%.

c. The "propeller resisting torque" may be expressed in a formula as follows:

$$T_p = F_b \, ARf$$

where T_p = propeller resisting torque (ft.lbs.)
F_b = elastic limit allowable crushing stress (p.s.i.)
A = total hub bolt bearing area (sq.in.)
R = bolt circle radius (ft.)
f = front flange factor (1.25 for splined flange, 1.00 for floating flange.)

d. T_p has been plotted against rated engine torque multiplied by the bore in Figure 9 for representative designs. 790 p.s.i. has been used for F_b for birch. (See Trayer, "Wood in Aircraft Construction", pp. 212-218.) Torque multiplied by the bore was used as a good criterion of the severity of the torque impulses from the engine.

e. The straight line in Figure 9 is a recommended minimum safe value for use in the conventional steel hub and wood propeller design. It may be expressed by the equation:

$$T_p = 1.4\,(T_E B) + 350$$

where T_E = rated engine torque (ft.lbs.)
B = cylinder bore (inches)

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* Neglected for several reasons; first, the actual amount of friction will vary considerably with the humidity of the air and tightness of the bolts; second, service failures have indicated the number and size of hub bolts rather than the size of the flanges to be critical.

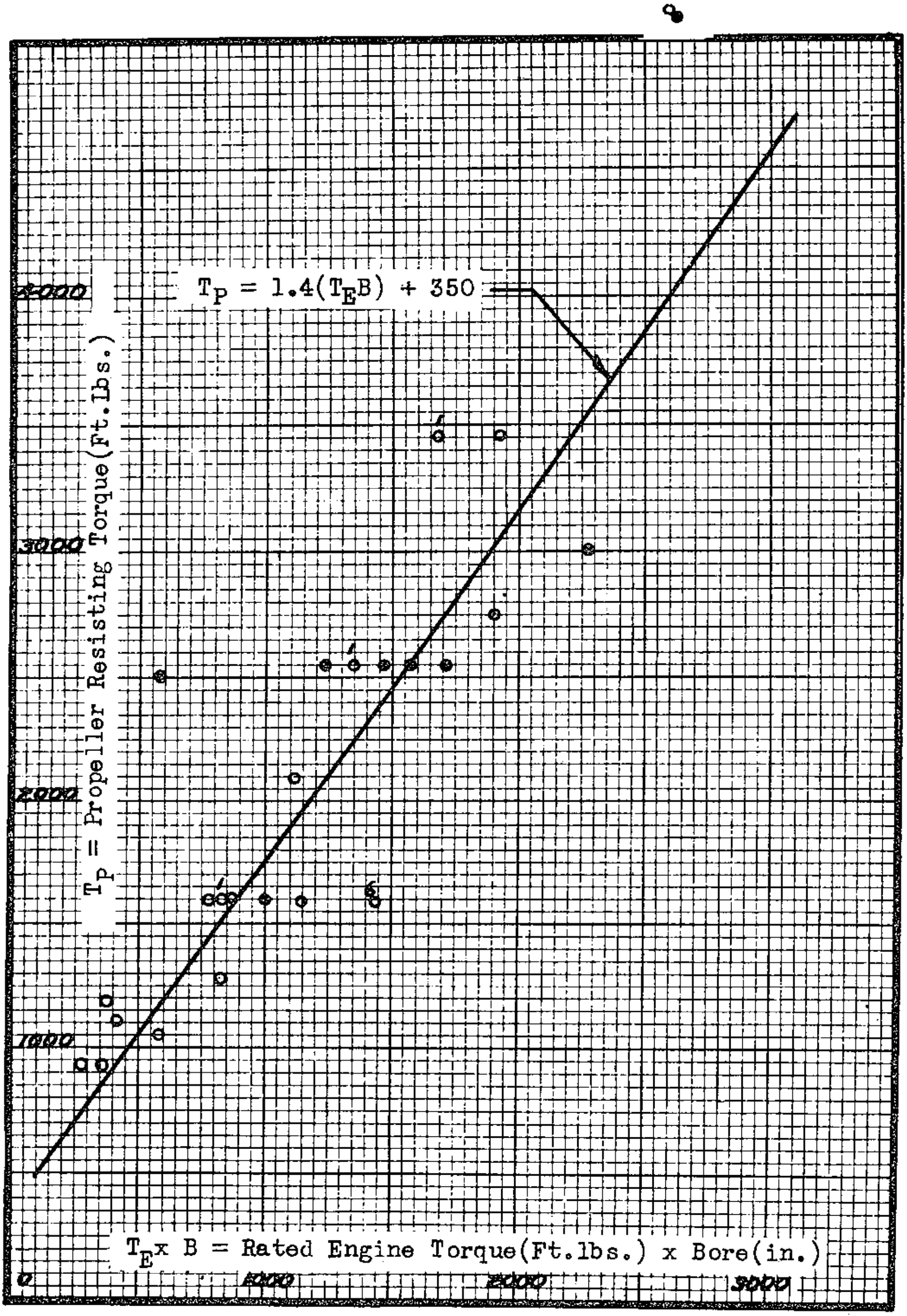


FIG. 9 WOOD PROPELLER BOSS STRENGTH CRITERIA

f. Each circle in Figure 9 represents a propeller and hub combination. The solid circles are those designs with a splined front flange and the open circles are those with a floating front flange. The number above the circle indicates the number of failures reported. In all cases the most highly stressed design is shown.

g. The three isolated cases of single failure may be disregarded since many identical designs are satisfactory. Faulty maintenance, such as loose hub bolts, may have been a contributing cause. However, the series of six failures for the one design is a definite indication of an unsafe condition and this particular design had to be completely changed before satisfactory results were obtained. For design purposes the material presented in Figure 9 and the equation in 14.1-B 7(e) herein should determine the number, size, and disposition of the hub bolts.

h. To further aid in determining the boss dimensions it is recommended that the length / diameter ratio of the hub bolts should not exceed eleven and that the clearance from the center of the bolts to the outer surface of the boss be a minimum of 2 1/2 times the bolt diameter. Center to center bolt spacing on the bolt circle should be 5 1/2 times the bolt diameter (minimum) and the center of the hub bolts should clear the center bore by 3 times the bolt diameter.

i. In considering design improvements it is well to recognize the critical portions of the design and the possibilities of relieving them. The highest local value of bearing stress is experienced in the wood at the hub bolts where they enter the rear flange of the hub and where the load deflection is least.

j. To relieve this portion of the material some designs incorporate a bushing at the rear flange to increase the bearing area of the bolts at this point.

7. Plastic wood propellers composed of compressed impregnated wood at the shank and encased in a reinforced cellulose-acetate covering have only recently been introduced in this country, hence they can only be noted in passing. Since this type of propeller blade is constructed with a steel shank casing, the hub design recommendations in 14.1-C herein should be adhered to wherever possible.

8. The subject of model designation is discussed here because the designer usually assigns such a designation. Although there is some precedent to the contrary, it is not considered advisable to approve a pitch range under one model designation. For the purposes of field identification it is essential that each pitch be assigned

a distinguishing dash number. For example, model 89B could be designated as 89B-48, 89B-52 and 89B-56 referring to pitches of 48, 52 and 56 inches respectively. The "89" as used could refer to the diameter in inches and "B" to the basic airfoil section. (See also 14.4-1 herein.)

C METAL PROPELLERS

The wide variation in metal propeller design, both in type and material of construction makes it impossible to advance many quantitative design criteria. The recommended tolerances and balancing methods have been given in 14.012-C herein. The following discussion will of necessity be somewhat generalized but specific recommendation is made whenever possible.

1. Blades of this type should conform to 6 CFR 14.11. The contour should be faired with respect to the planform. Abrupt changes in cross-section are to be avoided. Curves of maximum thickness and of minor and major moments of inertia versus radius may be necessary to check new designs. The center of gravity of the blade sections for controllable pitch propellers should lie on, or nearly on, a straight line along the axis of rotation. This line should have a slight forward tilt to relieve the aerodynamic loading of the blade. The blade fairing should avoid abrupt changes and the shank should be designed with this in mind. When the design incorporates an abrupt change of section, as in the butt-end attaching portion, as large a fillet as possible is recommended to reduce stress concentration at that point. Neglect of this has been a source of trouble in many designs.

2. All surfaces subjected to wear and corrosion should be suitably plated for protection against both. Cadmium has proven satisfactory as a steel hub plating with zinc and chromium among the possible alternatives. Cadmium has a somewhat higher salt water spray resistance than zinc in thin coatings (0.010 in.) but zinc plating is slightly superior to cadmium when exposed to air containing sulphur (city atmosphere). Both cadmium and chromium plated steel blades have given good wearing qualities. Aluminum alloy blades ordinarily have no protective coating but a chromic-acid anodic treatment increases their salt water corrosion resistance.

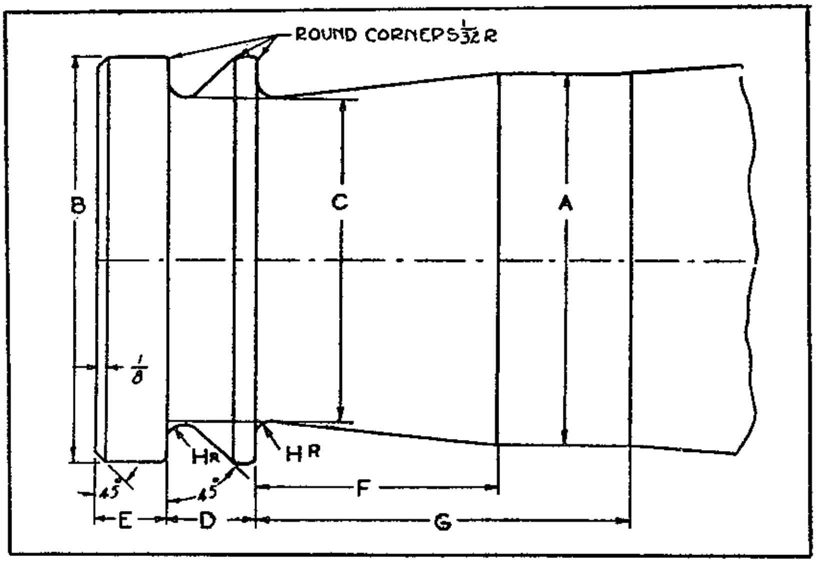
3. Metal propellers are inherently susceptible to resonance conditions and every effort should be made in the design to avoid such a condition in the operating range. All parts should be designed to minimize the effect of vibration upon their operation. This applies to the control mechanism as well as to the hub and blade structure. The control mechansim should be so designed

that a failure will not affect the functioning of the propeller other than to convert it into a fixed pitch propeller. Positive stops should be provided in the hub control mechanism so that designated low-pitch and high-pitch blade angles cannot be exceeded.

4. Blade tip sections should be designed with great care. Thin tip sections have caused trouble in metal blades and extreme thinness is to be avoided because the accompanying flexibility tends to promote resonance conditions. It does not follow that a thick tip insures against resonance, but a thick tip on a well-designed blade is preferable structurally if not aerodynamically.

5. In order to facilitate the interchangeability of parts it is recommended that the propeller design conform as far as possible to Army and Navy or SAE standards. The following dimensions are included for this purpose:

a. Blade end standards are given in Figure 10 and the accompanying table for detachable forged aluminum alloy blades. The fillet radii indicated should not be decreased in any case. It should be understood that this table does not define all possible sizes and that intermediate and larger sizes should be developed as the need becomes apparent. The horsepower is merely listed as a guide to show some of the usage of various size shanks. The values listed cannot be solely used to substantiate the airworthiness of an application for certification.



Usual HP per Blade Range	Blade End No.	A +.000 -.003	B +.000 -.003	C ±.010	D +.002 -.000	E ±.010	F ±.050	G +.06 -.00	H
0-25	00	2.250	2.495	2.000	0.500	0.4375	1.312	2.187	3/32
25-60	0	3.000	3.245	2.625	0.6875	0.562	1.687	2.937	1/8
60-100	1/2	3.4375	3.745	3.000	0.7812	0.6562	2.000	3.375	1/8
100-250	1	3.875	4.245	3.375	0.875	0.750	2.375	3.750	5/32
250-300	1 1/2	4.1875	4.620	3.6875	1.0625	0.875	2.6875	4.187	5/32
300-400	2	4.500	4.995	3.875	1.250	1.000	3.125	4.625	5/32
400-500	3	5.000	5.620	4.312	1.375	1.125	3.438	5.125	3/16

FIG. 10 - STANDARD ENDS OF DETACHABLE FORGED ALUMINUM ALLOYS BLADES.

b. Standard forged steel hub dimensions for the detachable aluminum alloy blade type are given in Figures 11 and 12.

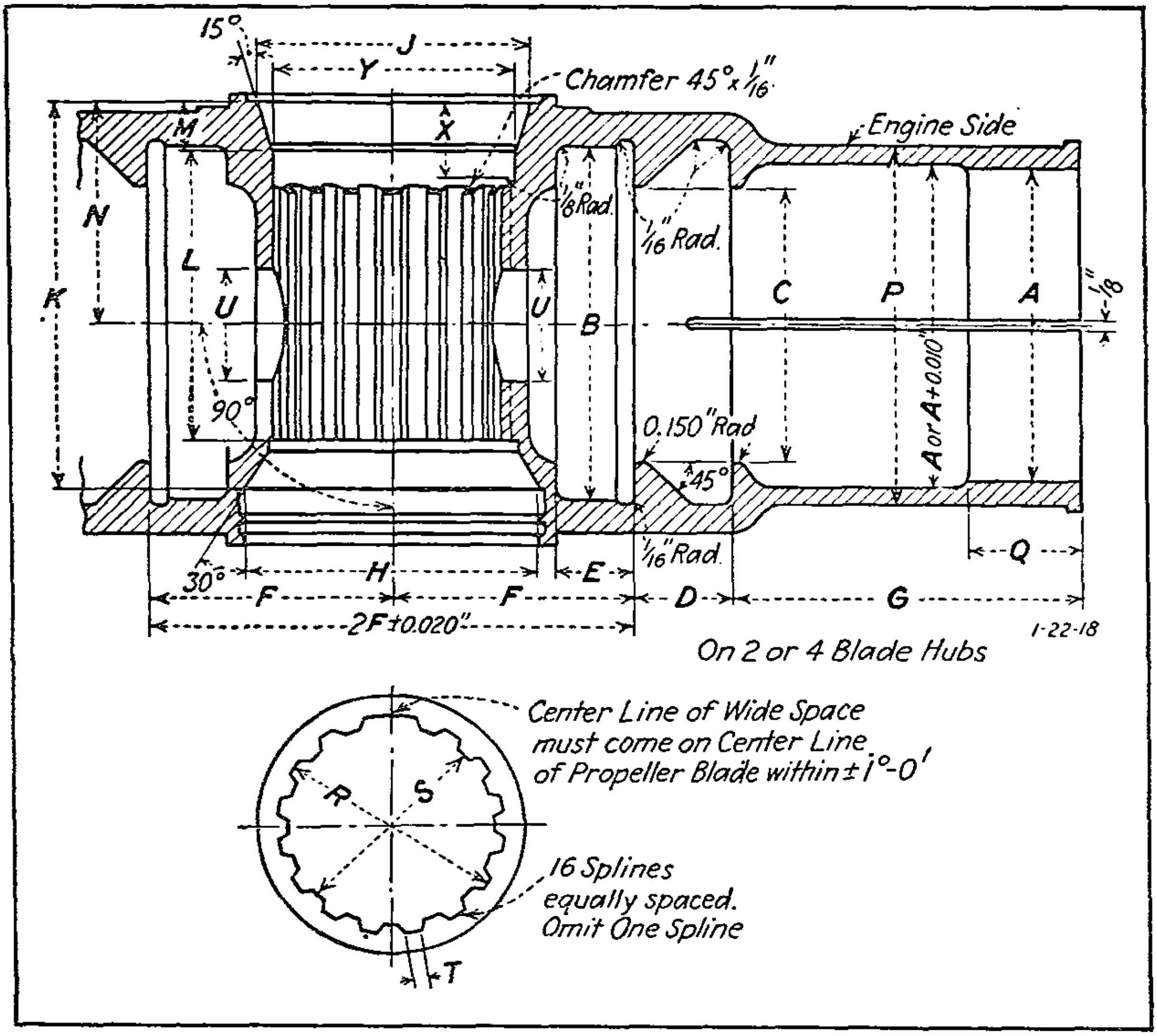


FIG. 11 - DETACHABLE ALUMINUM-ALLOY BLADE TYPE, FORGED STEEL HUB DIMENSIONS.

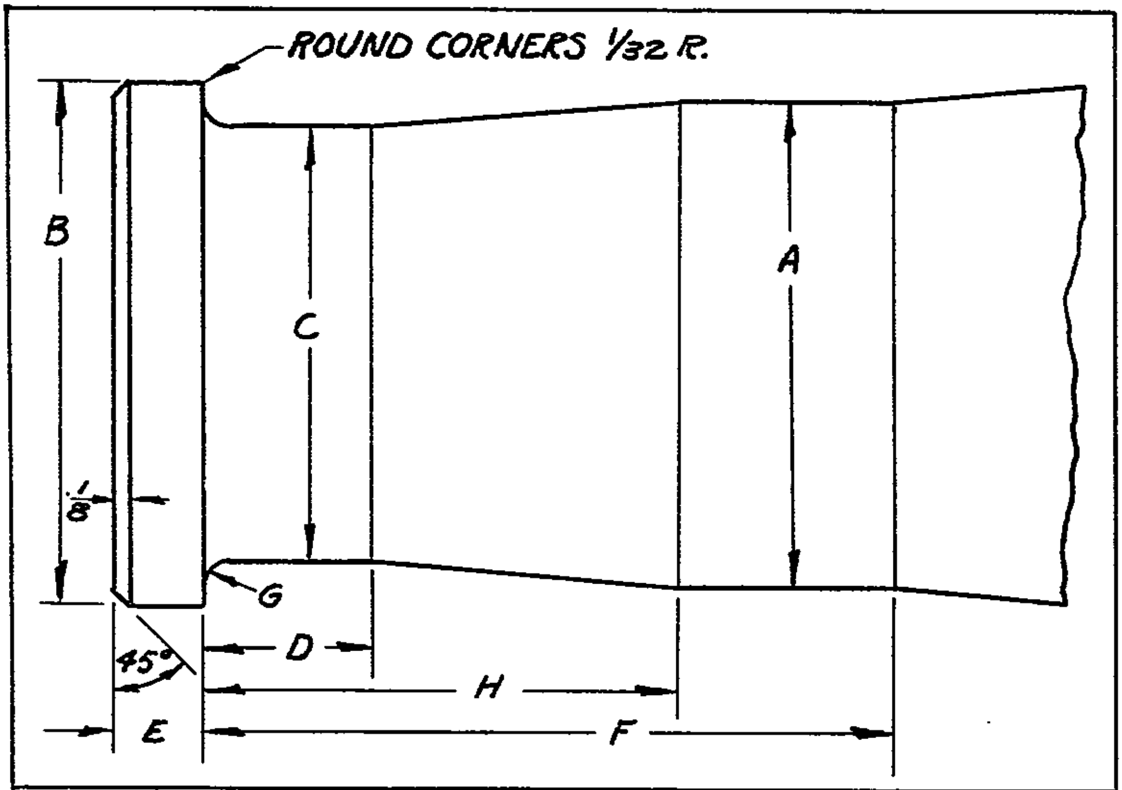
Blade No.	1	1	1 1/2	2	1	1 1/2	2	2
Hub. No.	20	30	30	30	40	40	40	50
A[1] +0.003 −0.000	3.878	3.878	4.190	4.503	3.878	4.190	4.503	4.503
B[1] +0.002 −0.000	4.247	4.247	4.622	4.997	4.247	4.622	4.997	4.997
C +0.010 −0.000	3.437	3.437	3.750	3.937	3.437	3.750	3.937	3.937
D +0.002 −0.000	0.875	0.875	1.062	1.250	0.875	1.062	1.250	1.250
E	13/16	13/16	15/16	1 1/16	13/16	15/16	1 1/16	1 1/16
F[2]	2.375	2.375	2.500	2.812	2.750	2.937	3.187	3.500
G	3 3/4	3 3/4	4 3/16	4 5/8	3 3/4	4 3/16	4 5/8	4 5/8
H +0.000	3.125	3.187	3.187	3.187	3.875	3.875	3.875	4.5625
J +0.000 −0.005	2.875	3.187	3.187	3.187	3.625	3.625	3.625	4.625
K	5 1/4	5 19/32	5 19/32	5 19/32	5 1/4	5 1/4	5 1/4	5 13/16
K (Ext'd.)	6 1/4	6 21/32	6 21/32	6 21/32	6 19/32	6 19/32	6 19/32	6 25/32
L	4	4 3/8	4 3/8	4 3/8	4	4	4	4 11/32
L (Ext'd.)	5 21/32	6 3/32	6 3/32	6 3/32	6	6	6	6 1/8
M	21/32	21/32	21/32	21/32	21/32	21/32	21/32	13/16
N	2 5/8	2 13/16	3 1/16	3 1/8	2 15/16	2 13/16	3	3
P	4 1/4	4 1/4	4 5/8	5	4 1/4	4 5/8	5	5
Q	1 1/2	1 1/2	1 5/8	1 5/8	1 1/2	1 5/8	1 5/8	1 5/8
R +0.005 −0.002	2.383	2.633	2.633	2.633	3.133	3.133	3.133	3.812
S +0.005 −0.002	2.164	2.414	2.414	2.414	2.881	2.881	2.881	3.562
T ±0.001	0.233	0.259	0.259	0.259	0.306	0.306	0.306	0.377
X	1 3/16	1 3/16	1 3/16	1 3/16	1 3/16	1 3/16	1 3/16	1 1/4
X (Ext'd.)	2 3/16	2 1/4	2 1/4	2 1/4	2 17/32	2 17/32	2 17/32	2 5/16
Y	2 13/32	2 21/32	2 21/32	2 21/32	3 5/32	3 5/32	3 5/32	3 27/32

[1] The center line of *A* and *B* shall lie within 0.002 in. of a plane perpendicular to the crankshaft bore center line. The center lines of *A* and *B* shall come within 0.002 in. of intersecting the crankshaft bore center line. The limits on the 90 deg. dimension is plus or minus 0 deg. to 1 min. The *A* and *B* bores shall be concentric with each other within 0.002 in. The hole *U* may be omitted at the discretion of the manufacturer.

[2] Shoulders located by *F* must be equidistant from center line of hub within 0.002 in. for perfect balance. Finish tolerances are ±0.010 in. unless otherwise specified.

FIG. 12 - FORGED STEEL HUB DIMENSIONS
(Refer to Fig. 11)

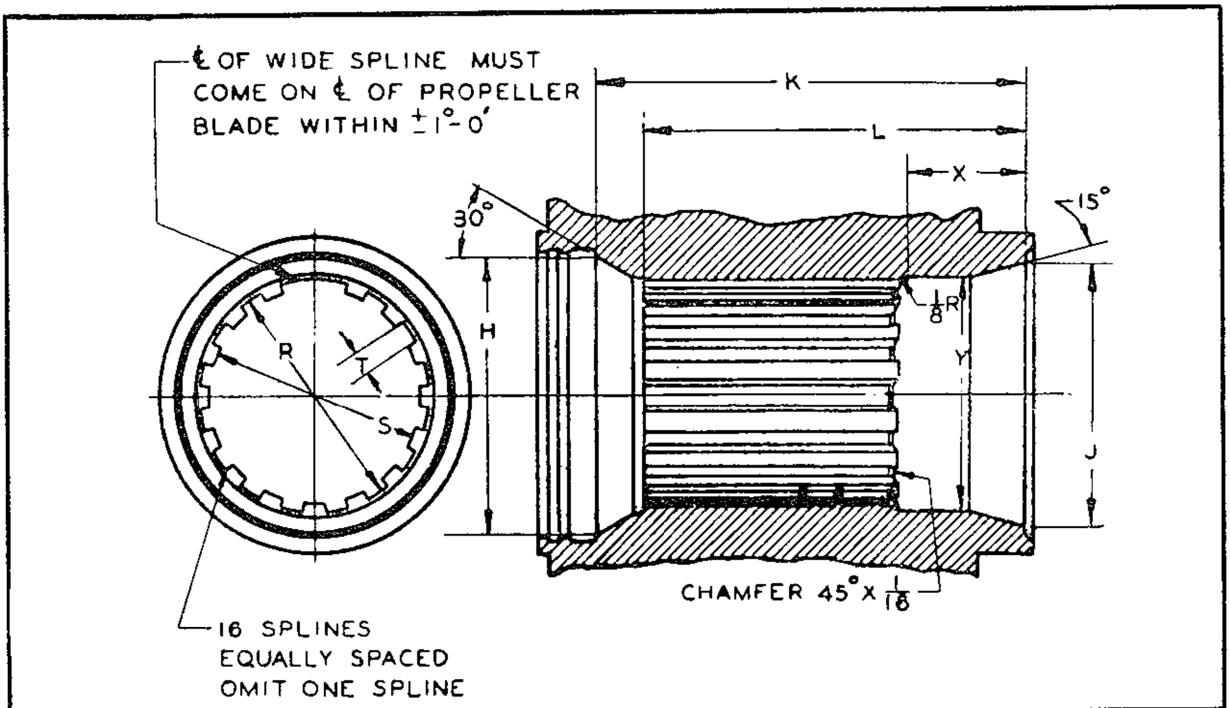
c. Standard dimensions for detachable hollow steel blade ends are given in Figure 13. It is recommended that blades of this type be sealed airtight and no vent holes drilled in the tip.



Blade End No.	A +.000 -.003	B +.000 -.003	C ±.010	D	E ±.010	F ±.010	G	H
00	2.250	2.495	2.000	35/64	0.4375	2.687	3/32	1.812
0	3.000	3.250	2.625	27/32	0.562	3.625	1/8	2.375
1	3.875	4.245	3.375	1 1/16	0.750	4.625	5/32	3.250
1 1/2	4.1875	8.620	3.6875	1 1/4	0.875	5.250	5/32	3.750
2	4.500	4.995	3.875	1 7/16	1.000	5.875	5/32	4.375
3	5.000	5.620	4.312	1 19/32	1.125	6.500	3/16	4.813

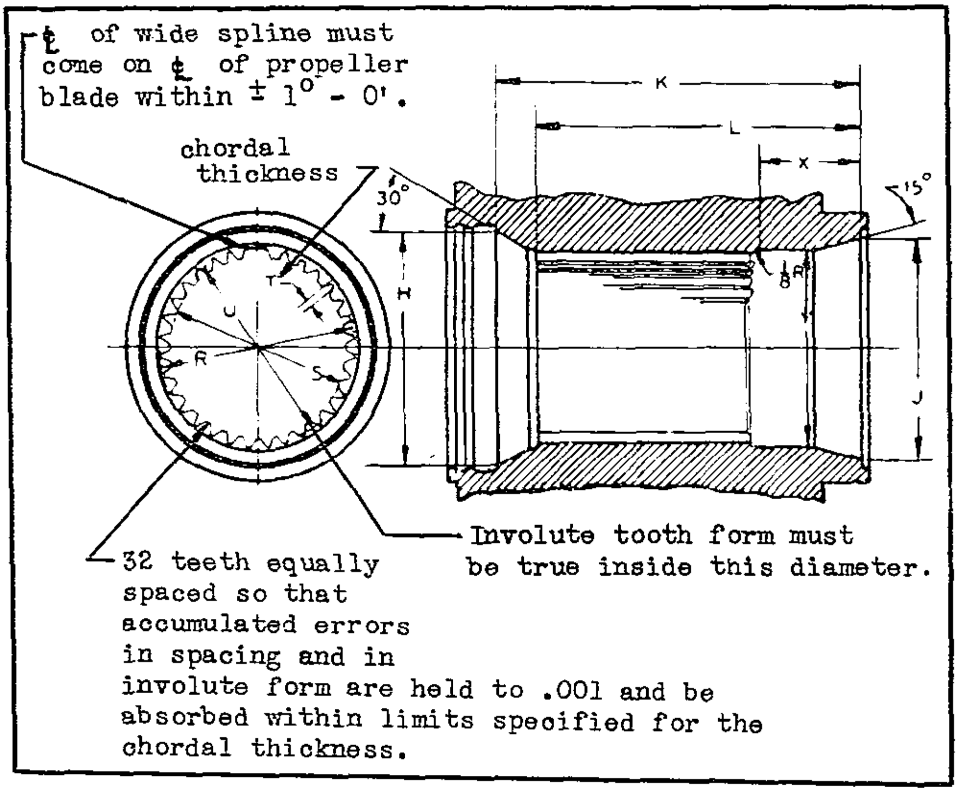
FIG. 13 - HOLLOW STEEL BLADE END DIMENSIONS.

d. Standard dimensions and dimensional tolerances are shown in Figures 14 and 15 for that portion of the hub of controllable propellers which mates with the engine shaft.



Shaft No.	+.000 H-.005	+.000 J-.005	K	L	+.005 R-.002	+.005 S-.002	T±.001	X	Y
20	3.125	2.875	6 1/4	5 21/32	2.383	2.164	.233	2 3/16	2 13/32
30	3.187	3.187	6 21/32	6 3/32	2.633	2.414	.259	2 1/4	2 21/32
40	3.875	3.875	6 19/32	6	3.133	2.881	.306	2 17/32	3 5/32
50	4.5625	4.625	6 25/32	6 1/8	3.812	3.562	.377	2 5/16	3 27/32

FIG. 14 - CONTROLLABLE PROPELLER HUBS (16 SPLINE).



Shaft No.	+.000 H-.005	+.000 J-.005	K	L	+.005 R-.002	+.005 S-.002	+.001 T-.000	U min.	X	Y
60	5.562	5.500	8 1/16	7 1/4	4.8014	4.4464	.2243	4.696	3 5/32	4 27/32

FIG. 15 - CONTROLLABLE PROPELLER HUBS (32 TEETH).

.2 COMMERCIAL PROPELLERS

.20 DATA REQUIRED

.200 1. The application for a propeller type certificate should be submitted on form CAA 01-9 supplemented by form CAA 14-1. The latter form should enumerate all the engines for which the propeller is designed. If a production certificate is also desired, form CAA 01-10 should be submitted. This form need only be submitted once for each general type, i.e., fixed-pitch, wood, etc., propeller.

.201 1. Drawings submitted should be complete in all important dimensions, specifications and identification data. The minimum essential details of a propeller drawing should incorporate the following information:

a. Title block details. (Locate in lower right-hand corner.)

(1) Company name and address.
(2) Model or identifying number of propeller or part.
(3) Date of drawing.
(4) Initials of draftsman and checker.
(5) All drawing change letters with date of change and description thereof.

b. Boss dimensions for fixed-pitch wood propeller.

(1) Diameter of engine shaft bore.
(2) Diameter of bolt hole circle.
(3) Size and location of bolt holes.
(4) Diameter and thickness of boss.
(5) Cross-section of boss showing location of hub wideners, if used.

c. Blade dimensions and details.

(1) Side elevation not dimensioned but with the line of centers of gravity.
(2) Plan view with the line of centers of gravity and detailed dimensions sufficient to check the general contour of the leading and trailing edges.
(3) Curve of maximum section thickness plotted against radius.
(4) Blade cross-section at frequent intervals (preferably every 6 inches).
(5) Chord and angle at each cross-section. (The section ordinates should also be given at the 10% stations of the blade chord. The leading edge section should be further divided into four equal sections and the ordinates given.)

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(6) When tipping is used, all details thereof.
(7) If the material is laminated, the extent and thickness of the laminations.
(8) A desired diameter reduction indicated on the blade planform by dotted lines.
(9) When a different pitch distribution from that of the basic model is desired, the stations and blade angles listed in a table on the drawing, and the model designation which applies to that pitch distribution.

2. A complete material specification list should be noted or referred to on the drawing. The standard Army, Navy or SAE specification should be referred to whenever possible. The exact finish to be used on each part of the propeller should be noted.

3. All dimensional tolerances should be specified or reference made to a table of these tolerances.

4. Drawings should preferably be accordion-folded to a 9 by 12 in. size with the title block showing.

5. Altered blueprints or altered photostats are not acceptable as they are a possible source of controversy.

.202 1. Duplicate drawings. If a small number of drawings are submitted they may be in duplicate in which case a sealed set will be returned by the Authority upon certification. In cases where a large number of drawings are involved much simplification is effected by submitting one set of drawings and a duplicate parts list. The parts list should be headed with the model number and date of issuance. It should show the drawing number, last change letter, and the name of each component part. Drawing numbers should be arranged numerically. Upon certification of the propeller the parts list will be sealed and returned for inclusion in the manufacturer's files. The drawings are filed in a general drawing file for each manufacturer, hence identical drawings for different models need not be re-submitted.

.203 1. The log should either be supported by the manufacturer's affidavit or signed by the witnessing inspector. A graphical or tabular engine log with 15 minute readings is acceptable. All stops should be noted and accounted for. Tests on other than fixed-pitch wood propellers must be witnessed by an inspector of the Authority or an authorized agent (See 14.21-1 herein) and the test log will be signed by such witness. Tests on conventional fixed-pitch wood propellers will ordinarily not be witnessed by an inspector. A new manufacturer's initial test will always be witnessed. Form CAA 14-2 (Appendix) has been developed to cover the nessed. Figure 16 includes the essential items of this type of test report and is available upon request. This type of report or its equivalent should be used.

FIG. 16 - FIXED-PITCH WOOD PROPELLER TEST REPORT

1. Test Data

(a) Propeller Model No. ______________ Serial No. ____________
(b) *Airplane License No.______________
(c) Engine Model No. _________________ Serial No. ____________
(d) *Total Period of Testing____________hrs., including
____________hrs. at ______________ rpm.
(e)**Total Period of Testing ____________hrs. at ___________rpm.

2. Test Report

(a) Comment on any evidence of excessive flutter or vibration during test. ________________________________
____
(b) Comment on any forced stops occurring during test. ________
____
____
(c) Describe tachometer calibrations made ____________________
____

3. Inspection after test

(a) Tipping and attachment:
Tipping cracked excessively ____________________
Rivets or screws loose _________________________
Satisfactory ___________________________________
Comments _______________________________________
____

(b) Condition of all wood joints:
Blade lamination joints opened up ______________
Hub lamination joints opened up ________________
Satisfactory ___________________________________
Comments _______________________________________
____

(c) Condition of hub bolt holes:
Elongated or burned ____________________________
No distortion __________________________________
Comments _______________________________________
____

Figure 16 continued -

(d) Condition of wood in general:
Longitudinal cracks ______________________
Transverse cracks ______________________
Comments ______________________
____

4. Conformity check

Item	Drawing	Measured
Overall Diameter		
Hub Diameter		
Hub thickness		
Diameter of hub bolt circle		
Station ___: chord		
max.thickness		
blade angle		
Station___: chord		
max.thickness		
blade angle		
Station___: chord		
max. thickness		
blade angle		

I hereby certify that the above testing, inspection and conformity check was supervised by myself and that the data presented herein is true.

State of______________________

County of______________________
(Signed) ______________________

Subscribed and sworn to before me this _______ day of ____________

19 ___.

____
(Notary Public)

* Applies to flight test only and must be supported by the airplane log.

** Applies to block test only and must be supported by the test log.

.204 1. A stress analysis is usually requested if the propeller is of a new design. While this is of minor value in itself it is useful as a check of future design changes and as a general indication of steady stress conditions. Such an analysis need not be exact in its treatment of blade-deflection, but all assumptions should be of a conservative nature and the analysis should include the basic aerodynamic and centrifugal loadings.

.21 TESTS REQUIRED FOR PROPELLERS OTHER THAN FIXED-PITCH WOOD PROPELLERS

1. Sufficient advance notification should be given of the expected starting of a test in order to provide for an inspector for the Authority to witness the test. In some cases military inspectors are authorized to act as inspectors for the Authority. Items in the test program about which there is any doubt should be discussed with the Authority at an early date.

2. Service failures and stress measurements available to date have indicated the necessity for obtaining vibration stress measurements of metal propellers under operating conditions. This is to determine the magnitude of the vibration stresses existing in operation and to determine if a critical resonance condition exists at any point in the operating range of the propeller. The essential equipment has been previously listed in 14.03-1(e)herein. The resultant oscillogram from the stress pick-up may be calibrated to read stress directly and therefore give the magnitude and frequency of the vibration stress at the pick-up location. These pick-ups should be mounted at points on the blade tip where the stress is deemed a maximum and at several points on the blade shank. Sufficient runs should be taken to establish the phase relationship between stresses at corresponding points of different blades and to determine the magnitude and predominant frequency of the vibration stresses over as wide an rpm range as possible, i.e., from take-off rpm down to 25% of that speed.

3. Crankshaft torsiograph records should also be obtained in order to determine the torsional characteristics of the propeller-crankshaft system. These runs should be made with the engine rigidly mounted in order to eliminate from the record any secondary vibration due to engine oscillations. The torsiometer should preferably be mounted at the propeller hub. The complete operating range should be investigated.

4. Linear pick-ups of the magnetic type should be suitably mounted on the engine to record the motion along the three axes and such displacement records correlated with the blade vibration-stress measurements for future installation problems. This material is considered secondary but very helpful.

5. The investigations discussed in the preceding three items should be completed as an essential preliminary to any actual endurance running and the results thereof discussed with the Authority before such endurance testing will be authorized. Based on such preliminary investigations the following conditions will apply:

a. If the vibration-stress survey shows no marked resonance conditions existing in the cruising or take-off regimes, the fifty hour endurance test may be run at either maximum, except take-off power and speed with a 10% increase granted for the take-off (one minute) operation or at 91% take-off power and speed with a 10% increment granted for take-off,(one minute) operation. It is recommended that 10 hours of the test be conducted at the take-off power and speed.

b. If the preliminary stress survey shows a marked resonance condition in the cruising regime it will be necessary to run a fifty hour test at the critical speed in addition to the testing outlined under item(a)above.

c. If the preliminary stress survey shows a marked resonance condition at take-off power and speed it will be necessary to run an added test under those conditions in addition to the testing mentioned under item a above. The amount of this testing will be based upon the amount of take-off operation to be expected in the normal service life of the propeller.

d. As an alternative to running the added test of item (c), the entire 50 hour endurance test may be run at take-off power and speed in which case no additional testing would be required. Tests mentioned under items (b) and (c) can, of course, be omitted by restricting operation of the propeller to avoid the critical conditions.

e. A correlation of stresses in new designs with those measured on designs with a satisfactory service record will be considered acceptable and helpful in a study of vibration-stress measurements.

6. The actual endurance test should be run on the type of engine for which certification is desired. Because of the vibration problems previously discussed it will ordinarily be impossible to assign a general power, speed and bore limitation to a propeller without further specifying the type of engine. The test should be run in minimum five hour increments, except that forced stops in these periods due to engine trouble will not affect acceptance of the test. A definite test schedule should be set up and adhered to as closely as possible. The propeller should be held to within 25 rpm of its proposed rated speed at all times during the test.

If the engine is operated at part throttle during the test suitable arrangements should be made to record the manifold pressure and a curve should be obtained showing the horsepower variation with manifold pressure at the proposed rated speed of the propeller. At each stop the propeller should be wiped off, examined, and a thin coating of used engine oil rubbed on. This applies to both steel and aluminum alloy propeller blades. The carbon and the trace of acid in the oil both clean the propeller and tend to work in and darken any crack which may have started.

7. It is essential that the pitch-changing mechanism of a controllable or automatic pitch propeller be operated throughout its usable range at least once for every hour of testing. These fifty cycles provide a check of the propeller operating mechanism throughout its full range. Any roughness in the operation of the propeller should be noted. Runs of five minute duration should also be made at approximately one degree intervals on this type of propeller whenever possible, and any variations in running characteristics should be noted. In addition to these required tests of the pitch-changing mechanism it is suggested that it be further subjected to a vigorous operation test of 500 cycles in the case of a manual control mechanism and 1500 cycles in the case of an automatic control mechanism.

.211 1. Although the static vibration tests mentioned in 6 CFR 14.211 are not considered essential data in view of tests discussed in 14.21-1 through 4 herein, it is desired that such tests be run and submitted for possible correlation with the actual stress measurements taken. Static vibration data should be adjusted for the effect of centrifugal force by use of the formula:

$$F_r^2 = F_o^2 + CN^2$$

where F_r = resonant frequency of the rotating propeller,
F_o = resonant frequency at zero rpm,
N = propeller rpm, and
C = vibration mode coefficient.

Suggested values of C for various loop and node conditions are:

C = 1.7 - 2.0 for 1-L and 1-N
C = 6.0 - 6.2 for 2-L and 2-N
C = 12.0 - 12.2 for 3-L and 3-N

2. A static vibration study should include a wide range of blade angles from 0 degrees to 90 degrees in order to determine the possibility of resonance conditions due to a forced vibration about the major axis. The effects of end fixity have been found to be important hence a suitable pre-loaded condition at the blade butt should be obtained to duplicate the effect of centrifugal force on that factor.

.22 TESTS REQUIRED FOR FIXED-PITCH WOOD PROPELLERS

1. The ten hour endurance block test should be run with the maximum diameter and pitch for which certification is desired. These dimensions may then ordinarily be reduced and approved without additional testing, provided that no other dimensions are materially altered and provided no increase in rating is desired. The test may be run on any internal combustion engine that may be available provided that the proposed rated rpm is maintained throughout the test. Since rpm is the only observed factor upon which approval is based it is essential that it be accurately determined. The tachometer should be calibrated before and after the test and checked with a stop-watch and revolution-counter during testing. This calibration should be noted on the test log. The speed should be held to within plus or minus 25 rpm of the proposed rating. The test may be made in suitable increments, provided that all stops are adequately explained in the test log.

2. The 50-hour flight test should be run on the same general type of airplane on which the propeller will be used and the specific diameter and pitch for which certification is desired should be installed. The engine power and speed should be equal to or greater than those for which the propeller is to be certificated and at least five hours should be run at the proposed rated speed. As the rpm is the only observed factor upon which approval is based it is essential that it be accurately determined. Suitable checks, as discussed in the preceding paragraph, should be made and noted on the test report. (See Fig.16)

.23 INSPECTION OF A TESTED PROPELLER

1. The propeller should be thoroughly inspected at the conclusion of the testing for any unsatisfactory conditions that may have developed. Pitch-control mechanisms should be thoroughly inspected for excessive wear and for clearances. A complete inspection report, considering all applicable items discussed in the following paragraphs, should be submitted.

a. Aluminum-alloy propeller blades should be etched at the tip and shank portions and at any other critical sections. Fillets, and points of abrupt curvature, are critical sections. The blades should then be examined for cracks with a 4 to 6 power magnifying glass. Particular attention should be paid within the tip portion to the region approximately one third back from the leading edge on the lower surface of the blade. Any transverse cracks or scratches near this location should be thoroughly investigated. The region of the shank in line with the leading or trailing edge of the blade should also be examined minutely.

b. Hollow-steel blades, solid steel blades and forged steel hubs should be thoroughly inspected visually, and magnetically by the wet process. Any pronounced magnaflux indication should be reported and discussed in detail as it may warrant a complete metallurgical examination. This inspection should be made by a highly skilled operator with a long service experience.

c. The blade control mechanism should be inspected for excessive wear, fatigue cracks, and any other unsatisfactory condition. All ferrous parts should be subjected to a magnetic inspection by the wet process.

d. The hub cones should be carefully inspected for any signs of wear which are an indication of torsional vibration condition.

e. Fixed-pitch wood propellers should be thoroughly examined for evidences of loosened or excessively cracked tipping, opened glue joints, cracks in the wood and local failure or cracking around the hub bolt holes. These items are adequately covered in Figure 16. A certain amount of flexural cracks in the metal tipping is considered normal.

2. The inspector for the Authority will inspect the torn-down propeller for conformity with the drawings which are to be forwarded to Washington. This inspection should be conducted and certified to by the manufacturer in the case of conventional fixed-pitch wood propeller tests. Several blade sections and other major dimensions of the blades and hub should be checked. Only a representative number of parts need be checked when a large number are involved, as in the hub control mechanism. A notation and record of the conformity inspection should be incorporated in the inspection report.

.3 MILITARY PROPELLERS

1. A requisite to certification of propellers of this type is the submittal of the proper forms and necessary drawings as discussed in the previous paragraphs 14.200 and 14.201, respectively.

2. A copy of the official report which forms the basis of the military approval or a copy of the official letter of approval from the military agency is required. The manufacturer's responsibility with respect to obtaining the letter is the same as in the case of the report. The propeller must be approved for service use. A restricted approval for additional flight test purposes is not considered sufficient.

.4 MODIFIED PROPELLERS

1. Small changes in pitch and diameter are ordinarily permissible in the case of fixed-pitch wood propellers without additional testing.

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For the purposes of field identification it is necessary that a new model number be assigned with each change in pitch and diameter. A change in dash number in conjunction with the basic model number is recommended to designate a change in pitch. (See 14.1-B (8) herein.) A change in pitch distribution should be noted in a suitable tabular form on the basic model drawings. Small changes in diameter which involve only the tip sections may be denoted by dotted lines on the basic model drawing. The necessary forms CAA 01-9 and 14-1 should be submitted for each model.

2. Minor modifications to a metal propeller blade structure may result in major changes in the vibration stresses of the blade. This point must therefore be suitably covered if a modification is submitted as minor. In general, appreciable changes in the structure of a metal propeller will be considered a major change and subject to the test requirements of 6 CFR 14.2.

SEALED DRAWING LIST

1. The sealed drawing list and sealed drawings should be kept adequately and conveniently filed at the manufacturer's office so that they are readily available for such conformity checks as may be made by representatives of the Authority. It is preferable to file each model separately in numerical order.

MAJOR CHANGES

1. Major changes to a propeller, as discussed in previous paragraph 14.4, will necessitate compliance with the test requirements of 6 CFR 14.2 and are treated as creating new designs. If there is any doubt as to whether a change is minor or major in nature, the decision should in all cases be referred to the Civil Aeronautics Authority.

MINOR CHANGES

1. Drawings including the minor changes made to the propeller during the preceding six months should be submitted during January and July of each year. If a drawing list was originally submitted the revised drawing list should also be included. If a drawing list was not originally submitted a duplicate set of drawings should be forwarded so that either a sealed drawing list or set of sealed drawings may be returned for file.

REDUCTIONS IN DIAMETER

1. Reductions in diameter made by cutting off the tip or by telescoping will generally be certificated without additional testing, provided the original design has no critical resonance conditions and it is shown that no additional critical resonance conditions are encountered in the smaller diameter blade.

SUGGESTED FIXED-PITCH WOOD PROPELLER INSPECTION FORM

Shipped to ______________________ Date Mfd. ____________ Des.No. __________

Address ____________________________________ Serial No. ____________

Wood Source ______________________________ Date rec'd. ____________

Hub Drilled ________________ by ______________________________

Hub Installed ________________ by ______________________________

Station	Angle	Plus or Minus	Width	Plus or Minus	Max. Thick-ness	Plus or Minus	Template Fit	Remarks

	Measured	Plus or Minus
Prop.Diameter		
Hub Diameter		
Hub Thickness		

Balance ______________

Track ______________

Finish ______________

Inspected by ______________

Approved by ______________

FIG. 17